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ABSTRACT

The Intermediate Science Curriculum Study (ISCS) is a large-scale instructional research project, designed to develop, test and disseminate into practice a system of individualized science instruction for grades seven through nine. This report outlines procedures of curriculum programing and subsequent analysis of the computer mode of presentation. Computer-assisted instruction (CAI) was selected specifically to provide formative evaluation information for the development of materials to be published in printed form for use in schools in the field. The report describes the program's development, first on the IBM-1400 and later on the IBM-1500 system, and the statistical evaluation of the programing and student responses. Appendices include comparisons of the first and third year CAI and field trial text materials, a sample of the printout material, and the enter and process codes used for the system. (JY)

CAI UTILIZATION FOR FORMATIVE CURRICULUM EVALUATION

TECHNICAL REPORT 1

ISCS

SUPPORTED BY USOE CONTRACT OEC 2-6-061762-1745 AND NSF GRANT GW-4235

THE FLORIDA STATE UNIVERSITY

TECHNICAL REPORT I
CAI UTILIZATION FOR FORMATIVE CURRICULUM EVALUATION

PREPARED BY

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MARCH 13
1970

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INTERMEDIATE SCIENCE CURRICULUM STUDY
DEPARTMENT OF SCIENCE EDUCATION
FLORIDA STATE UNIVERSITY
TALLAHASSEE, FLORIDA

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The research covered in this report is the product of many staff and graduate assistant contributions over the four year period involved. The overall responsibility of ISCS CAI evaluation had demanded the direction and coordination of a professional staff member. Dr. William R. Snyder insightfully served this role from 1966 to 1968. In the fall of 1968, Dr. Bobby R. Brown joined the staff, providing the essential leadership until the fall of 1969. From September 1969 until the present time, Dr. David D. Redfield has directed the overall ISCS evaluation effort.

Acknowledgement should be made of the early programming and proctoring efforts of Mr. Michael Stuart. In addition to proctoring, Mr. Paul Flood, Mr. David Dasenbrock, and Mr. Thomas Teates designed macros, programmed the test, and analyzed data for later materials. Throughout the entire period of ISCS CAI evaluation, Dr. Ernest Burkman, Project Director, supplied encouragement, guidance, and much helpful support.

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FORWARD

The ISCS Technical Report Series is intended to provide communication to other colleagues and interested professionals who are actively interested in research with and development of curriculum material. The rationale for the Technical Report Series is three fold. First to report in a concise, descriptive, and explanatory nature advances made in the technology of curriculum development. Secondly, pilot studies that show great promise with potential for further research and subsequent reporting can be given quick distribution. Third, the Technical Report Series provides for distribution of pre-publication copies of implementation studies that after proper technical review will ultimately be found in professional journals.

This report outlines procedures of curriculum programming and subsequent analysis of a computer mode of presentation of sequential science materials, grades 7-9. Such CAI application was specifically selected to provide formative evaluation information for the development of materials to be published in printed form for use in schools in the field. No claim is made that the procedures used are optimal or that they exploit the full capability of the medium. Rather the report presents the unique contributions of ISCS in developing a workable technology for such an application describing both strengths and weaknesses of the procedures utilized.

Ernest Burkman, Director
Intermediate Science Curriculum Study

March 13, 1970
The Florida State University
Tallahassee, Florida

GENERAL BACKGROUND ON THE INTERMEDIATE SCIENCE CURRICULUM STUDY

The Intermediate Science Curriculum Study (ISCS) is a large-scale instructional research project supported to date by a contract with the United States Office of Education and grants from the National Science Foundation. The project is designed to develop, test, and disseminate into practice a system of individualized science instruction for grades seven through nine.

The project is organized on a develop-field-test-revise design. Draft materials are produced at Florida State University by on- and invited off-campus personnel and tested on a large national sample of junior-high-school students. During the 1969-70 school year, more than 75,000 students in 25 states are involved in the field testing of the ISCS materials. In addition, a small number of students from the Florida State University campus school are taking a computer-assisted instruction version of the materials from which additional feedback data are being accumulated. To date, more than 400 scientists, teachers, and education specialists have cooperated in the development process.

The most unique feature of the ISCS materials is the fact that the students using them progress at different rates and through different instructional pathways depending upon their interests, abilities, and previous experience. The materials are being designed that this can be accomplished in ordinary science classrooms by teachers with limited special training.

The package of instructional materials for each grade level consists of student printed materials, specially designed laboratory apparatus, a student self-evaluation system based upon behavioral objectives established for the instructional materials, teacher orientation materials, and standardized tests. The Silver Burdett Corporation, in conjunction with Damon Educational Corporation, is distributing these materials during the experimental phase of the project and will market the commercial version of them.

The project has generated world-wide interest and its newsletter, published twice yearly, now goes to more than 10,000 people in 42 countries. ISCS materials are now in use in Australia and will be used in American dependent schools in Germany and Japan in September. Experimental testing of the materials is now underway in Manila, and plans have been established for a joint Florida State University - Philippines effort to produce a special Philippines version of the program. In addition, project personnel have visited Japan, India, and several South American countries for preliminary discussions related to possible use of the materials in these areas.

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Introduction

Much effort and substantial funds have been expended in developing Computer Assisted Instruction (CAI) as a specialized learning mechanism. In using this instructional medium efforts have been concentrated on a variety of learning studies involving extensive and ingenious schemes of presenting information to the learner or otherwise involving him in the learning process. The developing CAI technology is plagued by concerns of hardware expense, dearth of analysis and materials software, and a questionable future market for such a modality.

In 1966, the Intermediate Science Curriculum Study (ISCS) began a large scale curriculum development effort in which a specialized CAI application was envisioned as an economically defensible and uniquely valuable research and development tool for the curriculum developer. This anticipated use of Computer Assisted Instruction to assist in the formative evaluation of ISCS materials was evident in a then bold proposal by Burkman.[1]

> Using an adaptation of "coursewriter" techniques, the completed curriculum materials will be programmed for CAI in their entirety to permit logical, step-by-step presentation to the students. Because of the semi-programmed nature of the classroom materials to be produced, the task of converting them to a programmed sequence will not be as formidable as would be the case with conventional materials. In the programming process, every effort will be made to reduce to an absolute minimum the variation between the CAI and printed versions of the course with regard to structure, content, and wording.

[1] Burkman, E. (Principal Investigator) "A Project for the Development and Evaluation of a Coordinated Science Curriculum for Grades Seven Through Nine." A proposal for Research and/or Related Activities submitted to the U.S. Commissioner of Education for Support Through Authorizations of the Bureau of Research, Florida State University, Dec. 2, 1965.

As each student proceeds through the CAI program, his responses will be identified and stored in the machine on disc packs or cards for later analysis. This will produce an individualized record of the specific difficulties which various types of students encounter as they pass through the sequence. Such information should provide unique advantages in terms of the types of revisions needed in the general approach taken in the written materials as well as specific adjustments required for specific types of students. Hopefully, the analysis of the stored CAI performance data will provide:

1. A detailed breakdown of student performance on each step of the curriculum.

2. Suggestions as to appropriate branches which should be built into the curriculum to accommodate various categories of students. Such information could be utilized in building the supplementary curriculum materials (Excursions), in making the existing curriculum more effective, or perhaps in building parallel courses for various ability levels.

3. The step-wise performance data which can be correlated specifically to the reading and quantitative aptitude measures and to the achievement test or its sub-test.

Burkman had envisioned and proposed the ISCS model for the teaching-learning situation where much of the student's work is conducted independently. In this approach, the learning pace is set by the student, and the level of instruction is automatically adjusted to his ability.

To allow for individual differences in ability, two types of student materials have been developed. The primary sequence (core) for each grade provides the basic "story line" that every student follows. "Excursions" are materials that provide departures from the primary sequence. There are two kinds of excursions. Enrichment excursions are designed to provide greater challenge for the more able student, or for the student interested in pursuing a topic in greater depth. Remedial excursions provide the slower student, or less well-prepared student, with special background or skills needed for efficient progress in the core. Through selection and judicious use of excursions, the ISCS student or teacher may select a multi-track program specifically geared to the needs of the individual.

Both core and excursions are written in a semi-programmed style which permits students to proceed independently at their own pace. Thus the student text serves as lab guide and record book, as well as a source of conceptual and factual information.

The use of CAI was proposed as potentially the most appropriate and efficient means of monitoring in detail each student's individual progress and performance in such material. Witn such a monitor, the curriculum developer could hope to pinpoint the exact areas of the sequence that cause difficulty for specific types of individuals. Information of this sort could make the task of building and revising instructional materials easier and much more efficient.

The plan proposed and, in fact, essentially put into practice was to program each of the grade seven through grade nine science materials on a grade-a-year basis concurrently with the preparation of field trial versions of the same material. This allowed barely six months to complete the programming at each grade level. During this same time period at least half the student performance data had to be analyzed and presented to revision teams.

This report outlines the chronological development of the ISCS technology of utilizing CAI in this application. The procedures used and their effectiveness are reported as a guide to future researchers interested in similar applications to other subjects and grade levels.

THE IBM 1400 SYSTEM - A First Attempt

The formative evaluation of ISCS materials, using CAI, began in the fall of 1966. This corresponded to the first year of the classroom trial of the text materials. Simultaneously, a presentation of the ISCS program was made possible through the cooperative assistance of the staff of the Florida State University CAI Center. At the time, the CAI Center had an IBM 1400 computer with eight typewriter input-output terminals. With this system, all instruction and student responses processed by the computer were typewritten messages.

The problem immediately faced by ISCS was how this facility could be best adapted to satisfy the formative requirement. No group had ever undertaken so ambitious a task as programming for CAI presentation a whole year's course, much less a three-year sequential program. Further, formative analysis mechanisms were virtually nonexistent at the time. The task faced was formidible, particularly in the light of the fact that barely a three-months time period was allowed between the beginning of the preparation of field trial curriculum materials and the time that operating programs were available for CAI presentation to seventh grade subjects.

Procedures For Programming:

From the beginning, the chief goal of the ISCS use of CAI has not been to produce the best possible computer program for science instruction. The closer the match between computer program and classroom text the better. The focus, then, was on producing a detailed, accurate set of real student data for use in the preparation of a sound three-year course for classroom presentation.

This fact provided the critically needed basis for simplifying the task of the programming of student materials.

The programming language used for the IBM 1400 system was Coursewriter I. This language and the hardware that utilized it could not accommodate illustrations, graphs, or charts. Because the input-output procedure via typewritten messages was relatively slow compared to the student's reading rates, long passages of written text were frequently presented via a printed document called the student text. Data tables and graphs were also included in the student text. There was relatively little art work in the first edition materials, and this was provided by means of a series of 35mm slides to which students were referred by the computer or by their text.

Laboratory activities were done in the immediate vicinity of the computer terminal. Fortunately many of the activities did not require a large working area.

One critical question in the minds of the ISCS writers and CAI programmers was: Could the students do the coursework with the computer acting as teacher with no human direction-giving or assistance? The answer was a definite no! The aid of a proctor was required to explain some instructions and help develop certain critical concepts. The proctors also helped alleviate equipment malfunctions, handled equipment storage and inventory problems, and served as valuable on-the-spot recorder of observable "classroom" problems and computer program "bugs."

In an attempt to anticipate the questions of revision teams, large paragraphs were fragmented with specific questions. By increasing the number of questions, the programmers attempted to provide a more detailed, smaller-interval tracking of student behaviors for each test section. Declarative statements were frequently converted into interrogative ones. For example, suppose the classroom text was as follows:

"The blade of the force measurer is bent by the weight hanging on it." The computer program presented this statement as a question:

"What caused the blade of the force measurer to be bent?"

A set of multiple-choice responses followed, or the student was asked to type a free response answer.

To make sure the student knew the initial piece of information given in the declarative statement, he was then told by the computer whether or not his answer was correct; or he was told what the correct answer should be. In this way, each correct student response was reinforced. At the time, this programming technique seemed most appropriate in that it followed Skinnerian philosophy of programmed instruction. The effect these departures had on the programming philosophy of duplicating the textual materials was to produce substantial change in the CAI material as is shown in the sample of Chapter 5 duplicated in Appendix A.

Developing Analyses for Feedback to Revision Teams

Successful analyses mechanisms rarely materialize without careful planning at the data-collection stage. So it is with CAI even in its first year. The greatest single advantage of the 1400 system mode of instruction was the permanent typewritten copy of materials which could be taken away after each day's instruction. This hard copy facilitated review and study by the students (if they were so inclined) but also gave a detailed unabridged account of each student's performance to the evaluator. ISCS had anticipated that the programming protocol of increasing the questioning of the student would provide rich dividends in the form of revision information. A sample of this output is shown in Appendix B. Although only eight students were using CAI the first trial year, the volume of this output was entirely too overpowering to be digested and used by the writers in the limited time available to them. They needed and demanded more efficient and pointed information.

CAI formative evaluation did not come with ready-made data analysis programs. Moreover, the variety of computer languages and systems being used by CAI groups around the country varied so much that efforts to interchange analysis programs were fruitless. The FSU--CAI Center was and has remained in the process of developing and updating the capabilities of its data management system during much of the period of time that ISCS has been using CAI to evaluate its curriculum. Consequently, the provision of data for revision purposes has required the simultaneous and coordinated efforts of ISCS and CAI personnel to evaluate, utilize, and revise the data analysis procedures.

Through this joint effort, the ISCS writers were provided with several different types of information during the first year's CAI evaluation. For each chapter in the text, the data were summarized several ways. Each student response to each frame of information was recorded on magnetic tape along with various identification data for that student and frame. An elaborate sequence of data analysis programs was developed by CAI personnel to sort, edit, and merge the records in order to provide meaningful information summaries for the ISCS revision teams. The initial program provided a summary for every item which was encountered by at least one student. At the request of the ISCS writers, an alternate, more detailed program was developed to provide a listing of the first few characters of the actual responses of the students to each frame. This program also indicated whether each answer by each student was a correct answer (ca), wrong answer (wa), or unanticipated response (un). More elaborate student responses were recorded in printed data tables or on charts and graphs provided on separate sheets of paper as supplements to the CAI typewriter presentation.

The writers also had available a great deal of rather insightful, but not unique to CAI, proctor comments recorded on a day-by-day basis by the teaching assistants who worked in the CAI "classroom" Summaries of this information — conceptual problems identified by students, equipment design or structural inadequacies, etc. — by chapter were provided. In addition, the ISCS writers were given item analyses of comprehensive tests administered after every two or three chapters of text material. Notes taken during student-proctor discussions of the tests were also given to the writers.

Lessons Learned From First Year

The CAI data analysis procedures and the utilization of this information for revision of the first year version of the ISCS seventh grade student text were perhaps as valuable in indicating the possibilities for future practices and utilization as in aiding the revision team which had to produce the revised edition of the text. Some of the data collected during the CAI evaluation class in 1966-67 possibly could have been obtained in a regular classroom. However, the unique combination of detailed information on each individual student and the "classroom group" types of data obtained during the first trial year of CAI were most valuable for ISCS.

Some of the more important lessons learned for the use of CAI with the developing ISCS curriculum were:

1. It was possible through the use of Coursewriter programming language to completely program, proctor, and analyze the full year's course of instruction with two half-time graduate students and CAI Center support personnel under the part-time direction of one faculty member. Future programming could be done with the same manpower complement or less.

2. The revision of first trial materials is so intensive because of equipment, logic, and pedagogical considerations that programming and testing of first version material is not an efficient use of manpower and machine time. The strength of CAI for evaluation lies in its complete record-keeping, which makes possible a precise evaluation of materials. First version text materials -- at least the ISCS first version

materials -- do not warrant such a precise evaluation. Most of the changes that need to be made are gross and therefore quite obvious to a person trained in science or science education. CAI evaluation certainly identifies these problem spots, but unless there is an abundant supply of manpower, and unless computer time is inexpensive, data needed for first revision can be obtained more efficiently through regular classroom trial. For these reasons, only second version materials for any grade level have been evaluated via CAI since the 1966-67 trial year. The original plan to run a simultaneous CAI evaluation of the first year eighth-grade along with the second year seventh-grade materials was delayed until a year of classroom testing and subsequent first revision were completed on the eighth-grade materials.

3. New and more effective analysis routines were still needed to pinpoint particular problem areas. Manual data reduction of free responses and numerical data reported as student measurements were inefficient and most difficult to handle. Similarly, creative ways of tracking the nature and rate of student progress of both the individual and the group were sorely needed. In subsequent trial years, substantial technological improvement was made in these areas.

4. The decision to provide detailed, small-interval tracking of student behavior by increasing the number and specificity of questions in the CAI test versions gave unsatisfactory results. The substantial way in which these modifications changed the

instructional material placed the evaluator in the position of not being sure what effect knowledge of results and reinforcement were having on student learning. Therefore, progress could not be attributed to text design only.

Since the first year of CAI evaluation, the general approach used for the seventh-, eighth- and ninth-grade materials programmed for CAI presentation has been to preserve the exact wording of the text and to provide knowledge of results and reinforcement only when they are found in the corresponding textbook sections.

THE IBM 1500 SYSTEM --- A New Formative Technology

Prior to the start of the 1967-68 school year, the CAI Center at FSU installed an IBM 1500 System which provides both typewriter and light pen response capabilities along with cathode ray tube written and graphic instructional modes. Although ISCS did not enter directly into the decision-making procedure by which the CAI moved to the new system, ISCS did strongly support the change. Using the Coursewriter II language, the programming techniques afforded by the IBM 1500 System seemed to greatly increase the potential versatility of the CAI mode of instruction. Some of the increased capabilities of the system included: the use of graphic characters and animated figures along with the usual printed matter, increased rate and breadth of instruction presentation (now a paragraph of printed matter could be presented almost instantaneously at the student's request to continue, as opposed to the teletyped messages written a line at the time on the IBM 1400 input-output terminals), and alternative modalities in the man-machine interface (light pen or typewritten, multiple choice or free response).

Software for the Instructional Programs

The decision to match the CAI version of the textual materials as closely as possible to the classroom textbooks simplified the programming for the computer. A comparative sample of the CAI and field trial versions of the materials is shown in Appendix C. The increased use of a semi-programmed format with activity frames in the regular textbooks facilitated the preparation of their contents for computer presentation. The three factors — decision to reproduce text materials only, the new semi-programmed format, and the flexibility of the new Coursewriter II programming language — reduced by at least one-third the time required to complete the materials programming.

With Coursewriter II, there is a limited number of different formats required to present the basic kinds of materials found in the textbooks. As a result, all the ISCS materials programmed for presentation by the 1500 system were prepared for presentation via one of only ten basically different formats. Each of these formats is utilized in the form of a macro.[2]

Thus it is possible to program large quantities of textual material without the necessity of the programmer's typing each detailed statement for each frame of instruction over and over again. Only the unique text statements and unique parameters such as frame identifiers, response identifiers, and branching labels need

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[2]The macro is an input programming device available on the 1500 system which permits the programmer to use a card assembly procedure to call a detailed sequence of program statements. These statements may have required parameters inserted into designated locations by including the parameters in the single "call macro" statement written by the author.

to be entered by hand for each frame. Together with these unique statements, a single call macro statement is entered for each frame, and it may "call in" from 14 to 60 different additional statements for computer storage.

Obviously, the time and effort required to design, develop, and test a macro is justifiable only to the extent that there is reasonable utilization of the macro. ISCS has more than adequately utilized the macros developed by its staff -- in fact, in a real sense ISCS has evolved a comprehensive "macro based system of text input."

Because the current version of the ISCS programming techniques and procedures represents the culmination and broadest utilization of the macros developed over all the three years' efforts of the project, the characterization of these macros is given in terms of their present state of development. A brief description of each macro is given below, and detailed listings of the Coursewriter II statements of which these macros are constructed are available and listed in the ISCS Tech Memo 1.

The Macros. The ten different types of macros -- two of them with several different versions available to permit versatility such as designating any one of four possible answers as the correct one for a multiple choice question -- are described below. The significance of the use of these macros lies in their power to reduce writing and programming time and effort. These ten types of macros have served the purpose of inputting two versions (1967-68, 1968-69) of the grade seven year-long course, one version (1968-69) of the grade eight year-long course, and approximately one half (1969-70) (3 units) of the grade nine course. Had the macro mode of programming not been utilized, the computer language statement writing and programming time probably would have been three times as great as that actually required.

Macro	Mode*	Type of Text Programmed	Branches
ttd500	LP	Information Presentation.	Continue Review
exd500	LP	Branch to Excursion decision Frame	Excursion Next frame Review
ysd500	LP	Question which has a yes or no answer. Yes is the correct response. (A Variation provides for no as a correct response.)	Next frame (with selection of answer) Review
mad500	LP	Multiple choice questions, choice A is correct answer. (Variations provide for B, C, or D as correct answer.)	Next frame (via an answer) Review
rst500	LP	Resource decision frame. (Request one of 32 resources, used in geology unit only.)	Continue (to next frame) Call for resource Review
tst500	LP	Test question. (Any one of 4 possible answers can be programmed as "correct.")	Skip (to next question) Review (to previous question) Respond (to one of four possible answers).
dcd500	KB	Free response questions. No specified correct answer. (Limited to a one line response.)	Continue (by entering a response) Review

cmt500	KB	Free Response--no specified correct answer. May be from one to ten lines in length.	Continue (by entering a response) Review
lmd500	KB	Free response question with numerical answer. Limit function used to determine if an answer is within certain limits and therefore acceptable	Continue (by entering an answer) Review
kld500	KB	Free response question with correct alphanumeric answer. Keyletter function used to determine whether a response is acceptable.	Continue (by entering an answer) Review

*LP = light pen; KB = keyboard

There were also some important changes occurring in the thinking of ISCS regarding ways of programming which would better utilize the potential of CAI as a powerful evaluative tool. The first year's coding of frames was restricted to identification by chronological sequence within the program. This limited classification did not facilitate the investigation of the relationships between different science content and process themes. The development of a ten-character, alphanumeric code made it possible to identify each program segment and question according to its position in the text sequence as well as identifying the specific science content and process with which it deals and its remedial enrichment or diagnostic characteristics. It is now possible to retrieve these data in many different ways, depending upon particular evaluative interests.

For example, one may be interested in knowing if the difficulty of the concept of kinetic energy appears to be related to the difficulty with the concept of speed. The coding scheme may be used to single out all parts of the text related to these two concepts and investigate the student error rate (individual and/or group) for these items. This data bank and retrieval system make possible any number of specific investigations that are useful, not only in the revision of materials, but in investigating which particular content sequence is most logical to different kinds of students.

The process of coding each frame requires very little extra time and was found to be a most valuable asset in the analysis phase data reduction. The major exception to this statement is the time requirement for content and process coding. Although only one character was required to accommodate each function, several practical problems were experienced. A competent science educator was the only person who correctly assigned each frame valid code designations, and the time he took to do it more than doubled the total programming time to produce the CAI materials. Under the pressure of time available to get CAI programs operational for student trial, the complete coding of all frames had to be given up. As a result, dummy codes were used so that valid content and process codes could be added later in particular program segments for which revision teams requested such analyses.

Analyses of IBM 1500 System Data

Because of the many demands and problems of a first year's effort with the IBM 1400 system, it was impossible to make the most efficient use of the CAI evaluation in the textual revision during the summer of 1967. The data analysis provided the revision team was fairly complete, but the method of presenting it proved to be somewhat inappropriate. Two assumptions were made which later were decided to be in error.

First, the amount of time writers would have to examine the data in some detail before beginning rewrites was overestimated. Secondly, it was assumed that the writers should be provided with an unbiased presentation of the data, rather than an interpretation of what the analysis suggested about the materials. In this way, it was thought, the writers would be free to make their own judgments without the intervening bias of an interpreter.

Because time did not allow all the writers to fully digest the CAI data, it was apparent that efficient use of the kind of CAI data available to ISCS required a greater condensing of the records and a fairly specific interpretation of the data analysis. The decision was made to present each member of the revision teams a summary so that each writer could quickly see its relationship to trouble spots in the textual materials and what this relationship suggested about needed changes. These summaries were prepared on a chapter-by-chapter basis. Individual and group records for every student response were provided along with a rate of progress chart for each student and the percentage of correct answers for each question in the text.

This type of information has been generated and supplied to both the 1968 and 1969 summer revision conferences. The kind of information provided in these summaries is illustrated by the following paragraph.

> We find that the concept of kinetic energy is not being applied correctly by the student in Chapter 9 as indicated by the high error rate on Questions 9-34, 9-37, and 9-41. This appears to be related to the difficulty with the concept of speed in Chapter 6, Questions 6-12, 6-15, 6-16, etc. It may be possible to correct this by rewriting the first activity in Chapter 6, with special attention being given to the relationship of time and distance of the moving cart. It may also be necessary to write another remedial excursion dealing with division of decimals.

It is apparent that providing concrete suggestions of this sort greatly helps the writers in their revision task. The writers have stated their preference for this type of feedback format and point to a greater facility in incorporating the data provided into the total information pool used for revision decisions.

Several analysis programs were developed to facilitate the data digestion and presentation process making possible the type summary information provided the revision teams. A description of these programs and sample data obtained by their use are presented in the remainder of this section of this report. It should be noted that the descriptions given here represent the latest and therefore the most efficient and useful data analysis package ever used by ISCS for treating the CAI data.

The basic set of analysis programs available at the CAI Center is a part of the Data Management System (DMS) programming available to all users of the center. However, because ISCS has made a unique use of CAI, that of curriculum evaluation, only one of the DMS programs has been utilized effectively by ISCS. The ISCS staff has designed five programs which manipulate, reduce, and print out the data in a format that is utilized effectively by curriculum revision teams. Each of the programs in the ISCS data reduction and presentation package interfaces with and is dependent on the CAI Center's DMS. For input, the ISCS programs utilize magnetic tapes which contain merged and sorted data records produced by the DMS system. All the ISCS-DMS analyses are done on the 1500 system. The usual mode (and most useful for purposes of revision) of data presentation is printed listings, but some data can be obtained in the form of punched cards. Each of the analysis programs is briefly described below. Complete listings of the ISCS programs are given in ISCS Tech Memo 1 which is available upon request.

PROGRAM ISCSA:

All questions a curriculum revision team may ask cannot be anticipated in advance. A detailed listing or account of every student response can be used as an aid in answering questions which may arise at a later date.

A detailed listing is available from the DMS. However, because of the demand of other users of the CAI system, this listing provides all possible data from every student record in a format which allows only about 10 responses per page.

Program ISCSA provides a detailed listing by student, but in edited form, as output. Only that portion of the student record which could be of use to a revision team is printed. This consists of the student number, the question enter and process identifier (EPID), the response identifier (RS), the date of response, latency, and the response itself, if it is a keyboard entry. The printed output from this program is approximately one-fifth that of the DMS Version in terms of the volume of paper produced. Figure A illustrates the output from program ISCSA.

Student No.	EPID	RS	DATE	Latency (min.)	Keyboard Responses
Z756	AAEWMA0001	TM	09-24-68	0.46	
Z756	AAEWMA0002	TM	09-24-68	0.20	
Z756	AAEXMZ0103	RV	09-24-68	0.78	
Z756	AAEWMA0002	TM	09-24-68	0.09	
Z756	AAEXMZ0103	DC	09-24-68	2.00	BATTERYS
Z756	AAEYMA0004	TM	09-24-68	0.34	
Z756	AAEVMT0105	RV	09-25-68	9.83	
Z756	AAEYMA0004	TM	09-25-68	0.10	
Z756	AAEVMT0105	TM	09-25-68	0.11	
Z756	AEEFMX0206	CA	09-25-68	1.27	
Z756	AEEXM50307	TM	09-25-68	2.78	
Z756	AEEYMA0008	TM	09-25-68	0.18	
Z756	AFEOMY0409	TM	09-25-68	4.89	
Z756	AF5VMA0010	TM	09-25-68	0.34	
Z756	AF5VMA0011	TM	09-25-68	0.17	
Z756	AFEYMA0012	TM	09 25-68	0.06	
Z756	AFEXMS0513	OT	09-25-68	16.66	
Z756	AFEXMS0513	TM	09-25-68	3.48	
Z756	AFEXMA0014	TM	09-25-68	0.16	
Z756	AFEYMA0015	TM	09-25-68	0.09	
Z756	AFEVMT0516	TM	09-25-68	0.28	
Z756	AGEFMX0617	WF	09-25-68	4.14	THE
Z756	AGEFMX0718	RV	09-25-68	0.04	
Z756	AGEFMX0617	CF	09-25-68	1.21	STARTED TO BUBBLE

FIGURE A
ISCSA PRINTOUT

PROGRAM ISCSP:

This program provides a plot of student progress with respect to time. A graph is plotted for each student, with the frame number as the abscissa, and the time in minutes as the ordinate. A plot from Chapter 1, grade 7, is shown in Figure B.

```
TIME                      FRAME NUMBER
MINUTES

                   1111111111222222222233333333334
          1234567890123456789012345678901234567890

  0       .........................................
  5       .XXXX
 10       .   XXX
 15       .    X
 20       .    X
 25       .    X
 30       .    X
 35       .    XXX
 40       .      XX
 45       .       X
 50       .       X
 55       .       X
 60       .       X
 65       .       XXXXXXXX X
 70       .                XXXXX
 75       .                    X
 80       .                    X
 85       .                    XXXXXXXX
 90       .                          XXXX
 95       .                             X
```

FIGURE B
ISCSP PRINTOUT

A vertical plot indicates areas in which the student is spending most of his time. By scanning the learning materials at this point, it can be determined if this was expected, such as a laboratory activity, or if it was due to a question, which the student had difficulty answering. If the student does finally arrive at a correct answer, error analysis done would not indicate the student had difficulty with the question.

A horizontal plot identifies frames through which the student proceeded rapidly. A coinciding low error rate may indicate the sequence was too easy, whereas a high error rate might suggest the student guessed at the response with little thought or had a major misconception of the content. If there is a high error rate coupled with rapid progress for a series of questions based on laboratory activities it is possible that the activities are not doing the job well. It is also possible that the student did not complete the laboratory work and copied his results from a neighbor. For assistance in interpreting the pattern described above, the revision team member or evaluator might turn to the type of analysis output described next.

PROGRAM ISCST:

The program provides a trace of a student's progress with respect to response number. The frame number is plotted along the abscissa and the number of the response along the ordinate a sample trace is shown in Figure C.

```
RESPONSE                        FRAME NUMBER
 NUMBER

                                   111111111122222222223
                         123456789012345678901234567890
     0                  ...............................
     1                  .T
     2                  . T
     3                  .  D
     4                  .   T
     5                  .    O
     6                  .    T
     7                  .     C
     8                  .      T
     9                  .       T
    10                  .        T
    11                  .         T
    12                  .          T
    13                  .           T
    14                  .            T
    15                  .             T
```

FIGURE C
ISCST PRINTOUT

The data points are identified as the following type of response:

C = correct

W = incorrect

U = unrecognizable

O or T = latency only

R = renew

For a student constantly progressing forward, the slope of this trace is - 1. Departures from a slope of - 1 identify possible trouble spots in the instructional materials. ISCST is designed to flag and interpret two specific response patterns as are depicted in Figures D and E.

```
 1  .T
 2  . T
 3  .  D
 4  .   T
 5  .    T
 6  .     R
 7  .    O
 8  .    R
 9  .   T
10  .    T
11  .     O
12  .      T
13  .       T
14  .        R
15  .       R
16  .      R
17  .     R
```

FIGURE D
ISCST ZIGZAG TRACE

```
64  .        U
65  .        U
66  .        U
67  .        U
68  .        U
69  .        U
70  .        U
71  .        U
72  .        U
73  .        U
74  .        U
75  .        U
76  .        U
77  .        U
```

FIGURE E
ISCST UNRECOGNIZABLE RESPONSE TRACE

A zigzag trace, as in Figure D, indicates areas in which the student reviewed, proceeded forward, and reviewed again, perhaps in order to gain enough information to proceed. This could be caused by insufficient information in the instructional materials at that point or the inability of the student to understand the material.

A vertical trace of U's, as in Figure E, signifies unrecognizable responses by the student as diagnosed by the computer. This information is of great value in checking student progress if the monitoring teacher receives it daily. The teacher can identify those students with problems immediately, and determine whether difficulties are due to improper use of the CAI system by the student, or if there has been a legitimate response which the computer does not accept.

PROGRAM ISCSB:

In programming free response questions, which are characteristic of much of the ISCS text material, an inherent difficulty is how to anticipate all possible correct student responses. The student may type acceptable answers, which are not among those anticipated by the programmer. Unfortunately, these are judged incorrect by the computer. ISCSB is designed to pick only free response questions from the sorted master file and to print them as shown in Figure F.

CHAPTER 3
PAGE 5

QUESTION 16

IDENTIFIER
CEBWMX1637

Z751	WF	SPEED SHAPE
Z751	WF	SHAPE AND SPEED
Z752	WF	SHAPE, MOVEMENT
Z753	WF	SPEED DISTANCE
Z754	WF	SHAPE, SPEED
Z755	WF	DISTANCE, SPEED
Z756	WF	THE SHAPE AND DISTANCE
Z756	WF	THE SHAPE AND SPEED
Z756	WF	THE SHAPE AND SPEED
Z757	CF	SHAPE AND MOVEMENT
Z757	CF	SHAPE AND MOVEMENT
Z758	WF	DISTANCE, SPEED

FIGURE F
ISCSB PRINTOUT

A printout of this type serves two functions. First, acceptable but unanticipated answers may be detected, and their error status changed. Second, the incorrect answers may indicate the nature of the errors and the misconceptions that students have. This information serves well in the revision of the instructional materials. In the example illustrated in Figure F above, it is apparent that student Z 752 correctly answered the question, "The amount of change in _______ or change in _______ of some object can tell me how much force is being exerted." However, the programmers apparently required "and" as part of the answer -- an error on their part. Furthermore, if speed and distance are not acceptable as indicated, why do so many student say speed is part of the answer? Perhaps the materials leading up to this point need to be examined in order to determine possible causes of such a large percentage of wrong answers.

PROGRAM ISCSM:

Since its inception, data from the CAI trial have been presented in a variety of formats to the project staff. It has been found that for revision purposes, a matrix of responses has been the most useful format.

Figure G shows this type of output. The student numbers are listed down the left side of the page and the frame identifiers (EPID's) across the top. Two columns of response identifiers occur under the EPID. The first column under the EPID represents the first pass answer of the student. The second column under the EPID represents the student's last pass answer, if he reviewed back to that question and reanswered it. If this second column is blank, the student made only one pass and did not review.

ISCS8

	MATCH IDENTIFIER							
STUDENTS	DIOLMX1838		DIEPMX1939		DJEQMX2041		DJELMX2542	
Z801	CA		CA		WN		CF	
Z802	CA		WA		CA		WF	
Z803	WN		CA		CA		CF	
Z804	CA		WA		CA		WF	
Z805	CA		WA		CA		CF	
Z806	CA	CA	WA	WA	WN	CA	CF	
Z807	CA		CA		CA		CF	
Z808	WN		CA		CA	WN	WF	
Z809	CA		WC		CA		WF	
Z810	CA		WA		WN	WN	CF	
Z811	CA		CA		CA		WF	
Z812	WN		WA		WN		WF	
Z813	CA		CA		CA		CF	
Z814	WN		CA		CA		CF	
Z815	WN		CA		CA		CF	
Z816	CA		WA		CA		CF	
Z817	CA		WC		CA		CF	
Z818	WN		WA		CA		WF	
Z819	CA		WC		CA		CF	
Z820	CA		WC		CA		CF	
ERROR RATE	0.30	0.30	0.60	0.60	0.20	0.20	0.35	0.35

FIGURE G
ISCSM PRINTOUT

PROGRAM ISCSM:

Since its inception, data from the CAI trial have been presented in a variety of formats to the project staff. It has been found that for revision purposes, a matrix of responses has been the most useful format.

Figure G shows this type of output. The student numbers are listed down the left side of the page and the frame identifiers (EPID's) across the top. Two columns of response identifiers occur under the EPID. The first column under the EPID represents the first pass answer of the student. The second column under the EPID represents the student's last pass answer, if he reviewed back to that question and reanswered it. If this second column is blank, the student made only one pass and did not review.

ISCS8

MATCH IDENTIFIER

STUDENTS	DIOLMX1838		DIEPMX1939		DJEQMX2041		DJELMX2542	
Z801	CA		CA		WN		CF	
Z802	CA		WA		CA		WF	
Z803	WN		CA		CA		CF	
Z804	CA		WA		CA		WF	
Z805	CA		WA		CA		CF	
Z806	CA	CA	WA	WA	WN	CA	CF	
Z807	CA		CA		CA		CF	
Z808	WN		CA		CA	WN	WF	
Z809	CA		WC		CA		WF	
Z810	CA		WA		WN	WN	CF	
Z811	CA		CA		CA		WF	
Z812	WN		WA		WN		WF	
Z813	CA		CA		CA		CF	
Z814	WN		CA		CA		CF	
Z815	WN		CA		CA		CF	
Z816	CA		WA		CA		CF	
Z817	CA		WC		CA		CF	
Z818	WN		WA		CA		WF	
Z819	CA		WC		CA		CF	
Z820	CA		WC		CA		CF	
ERROR RATE	0.30	0.30	0.60	0.60	0.20	0.20	0.35	0.35

FIGURE G
ISCSM PRINTOUT

The error status of the response can be determined by observing the first letter of the response identifier in each of the columns. "C" indicates a correct response, "W" an incorrect response. The total error rate for each column appears at the bottom of the column. If there is no last pass answer, then for error rate analyses the first pass answer is also considered to be the last pass answer. Questions with a high error rate can easily be detected by a quick look at the matrix, and the reason for the high error rate may then be investigated.

OTHER MATRIX OUTPUT:

The matrix format allows for easy scanning of all student first pass responses to a single question, or an individual student's response to successive questions. Because of this functional property, it was decided to format other data in the same way. Figure H shows a matrix of latency times, Figure I a matrix of the number of reviews on each frame, and Figure J a matrix of the date of response for each frame.

ISCS7

STUDENTS	CBBVMT0209	CB3XMA0010	CB3YMA0011	CCBJMY0312
	LATENCY IN MINUTES			
Z751	0.0	0.0	0.1	0.0
Z752	8.4	0.7	0.1	5.5
Z753	3.4	0.2	0.5	0.7
Z754	11.8	0.2	1.1	0.7
Z755	9.9	0.2	0.4	0.2
Z756	0.1	2.0	1.0	0.8
Z757	3.4	3.8	6.0	4.8
Z758	8.8	0.4	0.1	1.0
Z759	8.0	0.3	0.3	0.4
Z760	8.6	3.9	0.3	0.6
Z761	0.5	0.3	0.2	0.6
Z762	4.6	0.2	0.1	1.4
Z763	0.0	0.0	0.0	0.0
Z764	23.4	1.3	1.5	0.2
Z765	0.8	9.6	0.2	1.6
Z766	8.2	0.1	0.4	0.7
Z767	24.6	0.1	0.2	2.1
Z768	6.9	0.8	0.8	4.5
Z769	9.2	1.9	0.0	1.5
Z770	6.5	0.3	0.5	1.1
AVE LATENCY	7.35	1.31	0.68	1.41

FIGURE H
MATRIX OF STUDENT LATENCY
BY FRAME

A quick look at the average latency data in Figure H indicates that the first frame (CBBVMT0209) required much more time (7.35 minutes) to complete than did any of the others. The third frame (CB3XMA0011) required the least amount of time (0.68 minutes) on the average.

A closer look at the latencies for the first frame reveals that this larger time was a general characteristic of most of the students at this point in the program. A few students, Z751 and Z763, for example, had very low latencies, indicating that they probably skipped over the frame. Other students, Z764 and Z767, required extremely long times to complete the frame. The frame in question instructed the students to complete an activity (stretching a rubber band) in the laboratory. The latency data are quite varied, and one may assume that some students either did not do the activities or had done them at some time other than when instructed to do so. Other students apparently got so involved with or distracted by the activities that they took a very long time to complete the frame, they might have had trouble finding the equipment!

The relatively short latency times for the second and third frames are related to the fact that these are both information presenting (reading only) frames. The shortest frame in this set of four is the third one. The fourth frame directs the student to plot one point on a graph in his student text.

The average latency has proven to be a good estimate of how long it takes an "average" student to complete a particular frame. Frequently, this type information causes the revision team to question seriously whether or not a particular activity or chain of frames is worth the time it takes students to complete it.

ISCS7

NUMBER OF REVIEWS

STUDENTS	CBBVMT0209	CBBXMA0010	CBBYMA0011	CC3JMY0312
Z751	0	0	0	0
Z752	0	1	0	0
Z753	0	0	0	0
Z754	0	1	0	0
Z755	0	0	0	0
Z756	0	0	6	1
Z757	0	0	0	1
Z758	0	0	0	0
Z759	0	1	0	0
Z760	0	2	0	0
Z761	0	0	0	0
Z762	0	0	0	0
Z763	1	2	15	2
Z764	0	1	0	1
Z765	0	0	0	0
Z766	0	0	0	0
Z767	1	0	0	0
Z768	2	2	0	0
Z769	0	0	0	0
Z770	0	0	0	0
TOTAL	4	10	21	5

FIGURE I
MATRIX OF STUDENT REVIEWS BY FRAME

The matrix shown in Figure I is a valuable aid to formative evaluators who are concerned with whether students have to review through materials frequently --- possibly indicating some lack of clarity in the materials. The total of 10 reviews for the second frame in the sequence suggests that some revision of the text in that frame may be needed. The fact that the reviewing was done by several students lends weight to the need for revision. The total number of reviews for the third frame was the highest (21) but all 21 reviews were done by only two students. This may indicate that these two students needed special attention at this point in the course -- either help or control of their tendency to "play around!"

DATE OF RESPONSE

STUDENTS	CA99MA0001	CAB2MA0002	CABXMA0003	CABXMY0104
Z751	10-25-68	10-10-68	10-10-68	10-10-68
Z752	10-30-68	10-22-68	10-22-68	10-22-68
Z753	10-15-68	10-15-68	10-15-68	10-15-68
Z754	10-16-68	10-17-68	10-17-68	10-17-68
Z755	10-11-68	10-11-68	10-11-68	10-11-68
Z756	10-09-68	10-09-68	10-09-68	10-09-68
Z757	10-21-68	10-21-68	10-21-68	10-21-68
Z758	10-11-68	10-11-68	10-11-68	10-11-68
Z759	10-10-68	10-10-68	10-10-68	10-10-68
Z760	10-21-68	10-21-68	10-21-68	10-21-68
Z761	10-11-68	10-11-68	10-11-68	10-11-68
Z762	10-10-68	10-10-68	10-10-68	10-10-68
Z763	10-11-68	10-11-68	10-11-68	10-11-68
Z764	10-21-68	10-21-68	10-21-68	10-21-68
Z765	10-24-68	10-24-68	10-24-68	10-24-68
Z766	10-15-68	10-15-68	10-15-68	10-15-68
Z767	10-30-68	10-30-68	10-30-68	10-30-68
Z768	10-18-68	10-18-68	10-18-68	10-18-68
Z769	10-10-68	10-10-68	10-10-68	10-10-68
Z770	10-22-68	10-22-68	10-23-68	10-23-68

FIGURE J
MATRIX OF STUDENT DATE OF RESPONSE

The date of response matrix gives a quick overview of how far apart the students were time-wise at a given point in a specific chapter. In the data reproduced in Figure J (chapter 3) the time spread on the first frame was from 10-9-68 to 10-30-68, or about three weeks. This matrix makes it possible to check quickly the approximate progress of the class as a whole or of any individual within the class.

COURSE ISCS9 012
STUDENT V128

DATE	E.P.I.D.	RESPONSE	LATENCY
01-16-70	LE023 01HD	1ST DAY, NO CLOUD COVER, 2ND DAY,CLOUDY,	147.1*
01-16-70	LE023 01HD	3RD DAY, CLOUDY 4TH DAY, PARTLY	136.9
01-16-70	LE024 01HD	THE OBSERVATION OF TEMPERATURE DIFFERE	294.7
01-16-70	LE024 01HD	NCE AND WIND DIRECTION CHANGE COULD HAVE	98.5
01-16-79	LE024 01HD	TOLD ME THAT A LINE OF TEMPERATURE DIF	65.2
01-16-70	LE024 01HD	FERENCE WAS	62.9
01-16-70	LF028 01HD	1ST DAY, CLEAR 2ND DAY PARTLY CLOUDY, 3R	131.8
01-16-70	LF028 01HD	D DAY, CLOUDY 4TH DAY,	81.4

*Latency in Seconds.

<u>Question List</u>

LE023 5-10. List changes in the cloud types as the line approached and moved through Fargo:

LE024 5-11. What observation could have told you on days 1 and 2 that a line of temperature difference was approaching Fargo?

LE028 5-13. List changes in the cloud cover in Selma as the line of temperature difference passed through:

FIGURE K
INDIVIDUAL STUDENT COMMENTS

A second type of analysis procedure provided a listing of all students responses to each question printed in sequence by question. This listing was prepared for the revision team charged with evaluating and revising the unit to which the feedback pertained. This procedure provided a means of getting the actual student responses to each open-ended question directly to the revision team in printed form. The sample of this listing shown in Figure L is the response list for question 5-10. "List changes in the cloud types as the line (temperature difference) approached and moved through Fargo:"

*** CAI ** FSU ***

COURSE DATE	ISCS9 E.P.I.D.	RESPONSE	LATENCY
12-04-69	LE023 01HD	NOT CLOUDY THE FIRST DAY, COMPLETELY	48.8
12-04-69	LE023 01HD	CLOUDY THE SECOND AND THIRD DAY, AND	46.2
11-24-69	LE023 01HD	STRATOS TO CIRRUS AND	26.9
01-05-70	LE023 01HD		5.1
01-05-70	LE023 01HD	1ST DAY-CLEAR	23.7
01-05-70	LE023 o1HD	2ND DAY-CLOUDY	30.3
01-05-70	LE023 01HD	3RD DAY-CLOUDY	29.8
01-05-70	LE023 01HD	4TH DAY-PARTLY CLOUDY	24.5
11-24-69	KE023 01HD	STRATAS TO CIRRUS TO	31.4
01-08-70	LE023 01HD		2.5
01-08-70	LE023 01HD	DAY1 THE TEMPERATURE IN FARGO SHOULD DECR	41.2
01-08-70	LE023 01HD	EASE OVER NIGHT BECAUSE THE WARM AIR IS	43.9
01-08-70	LE023 01HD	APPROTCHING THE CLOUDS SHOULD BE CLEAR U	144.8
01-08-70	LE023 01HD	NTIL THE NEXT DAY DAY2 THE CLOUDS SHOULD	32.4
01-08-70	LE023 01HD	BE FOGGY IN TO THE NIGHT AND THE NEXT DA	39.2
01-08-70	LE023 01HD	Y DAY3 THE CLOUDS SHOULD BE CLEARNING UP	44.7
01-08-70	LE023 01HD	AND BE CONTENUALLY CLEAR THROUGH THE 4	44.8

*Latency given in seconds.

FIGURE L
SUMMARY OF STUDENT COMMENTS

SUMMARY

ISCS in its utilization of CAI for formative evaluation has evolved techniques valuable in the preparation of a three-year science course for classroom presentation. Experience showed that it is feasible to utilize CAI in the evaluation of an activity centered course, when:

1. laboratory space is made available in some nearby area preferably next-door to the terminal area.
2. diagrams, figures, and data tables which are difficult or impossible to program are provided to the student in a supplemental booklet for his reference and keyed to the CAI program directly.
3. text materials are replicated as closely as possible for CAI presentation.
4. using the aid of programming macros.

Year-long courses <u>can</u> be replicated and presented to classroom groups via CAI. The time required to prepare all operating CAI versions of a one year long course was approximately:

3 man-months for programming and preparing companion supplement book
1 1/2 man-months for entering a system
2 man-months for proofing and debugging

The presence of a classroom teacher is not only desirable, but mandatory for CAI presentation of a laboratory course which closely parallels a textbook designed for a classroom in which the teacher serves as a resource person.

Although it is desirable to provide students with a written record of their course-work as was done with the IBM 1400 system, the advantages offered by the more versatile 1500 system with the CRT capability outweigh the lack of a typewritten record for the student to keep.

For most efficient use by revision teams, the voluminous data generated by CAI programs need to be summarized and interpreted by evaluation group personnel. It is not reasonable, and probably not practical, to expect curriculum writers to reduce vast quantities of detailed data before making decisions about how to revise a chapter or a page. A number of unique analysis programs were developed for this purpose.

The use of a EPID code for each frame in a 1500 system program provides an efficient means by which data can be identified during sorting, analysis, and summarizing procedures. The time involved in pre-coding each frame for its eventual use is well worth the investment. The most time consuming portion of the coding procedure is the decision making regarding content and process codes. These latter two codes can be omitted where use is not anticipated and the EPID still retains such critical information as position in sequence, type of question or type response.

To obtain the greatest value from the detailed records obtained from CAI, ISCS found that second (or later) trial materials should be programmed for CAI presentation rather than the first year's materials which tend to contain the larger gaps or errors that can be detected and corrected readily by evaluation techniques other than CAI.

Appendix A

Comparison of CAI and Field First Year Trial
Text Materials

TEXTBOOK

CHAPTER V

"EXPERIMENTING" WITH DRAG

You have probably concluded by now that there must be something special about the force that you have been calling "drag." It keeps coming up again and again. "Drag" involves what is probably the most important force known -- the force of friction. It is so important that we will devote this entire chapter to studying it. As you study friction you will also be learning about one of the most important tools of science -- the experiment.

To start our study, you will need to remove the box from the balloon-elevator you used in previous chapters. Then attach a string to the box. Put two metal cubes in it and place it on the floor. Pull on the string until the box just begins to move. How much force is needed to start the box moving?

CAI TEXT

CHAPTER 5

"EXPERIMENTING" WITH DRAG

5.1 qu
You have probably concluded by now that there must be something special about the force that you have been calling "drag." It keeps coming up again and again. ---- involves what is probably the most important force known -- the force of friction.
ca drag
ty Right
un Take a look at the previous sentence. Look for a four letter word that means the same thing as friction. It stands out like a sore thumb.
"____"
Type it.
un Type drag

5.2 gu Friction is so important that we will devote the entire chapter to study it. As you study friction, you will also be learning about one of the most important tools of science -- the experiment.

To start your study, check to see that you have the box from the balloon elevator in your equipment. Attach a string to the box. Now put two metal cubes in it, place it on the table, and pull on the string until the box just begins to move. Type the time when you finish.
ca

5.3 gu How much force was needed to start the box moving?
(1) 5 Newtons
(2) 500 Newtons
(3) Not very much force
(4) Quite a bit of force
(5) I can't tell for sure.
ca 5
ty Right. That's probably the best answer.
wa 1
wb 2
ty How can you say that without measuring it? Try again.
wa 3 Perhaps it isn't much compared to that for pulling an elephant but it's a lot compared to pulling a flea. Try again.
wa 4
It's quite a bit compared to pulling a flea but not much compared to the force needed to pull an elephant. Try again.
un Type either 1,2,3,or 4. Try again.

TEXTBOOK

Here again is the same question you have not been able to answer up to this point. But now your force-measurer gives you a way to find the answer.

Set up a force-measurer as shown in Figure 33. Find a classmate to help you for the next few minutes.

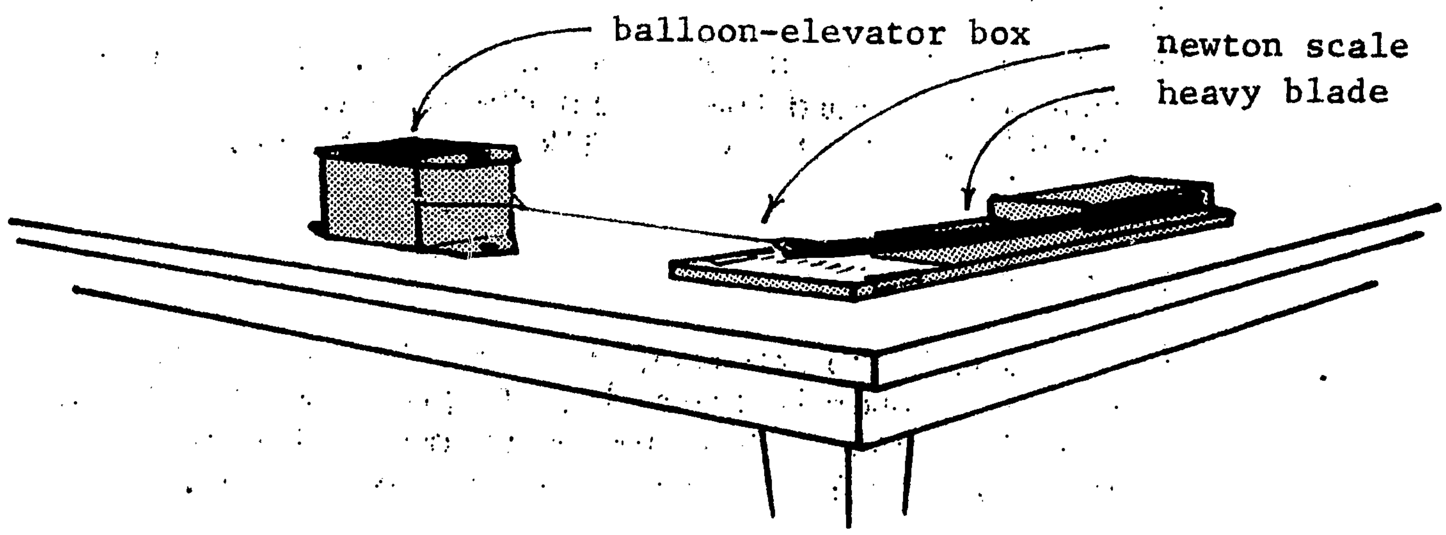


Figure 33.

Be sure the card labeled "newtons" is clipped in place and that the metal blade (the heavy one) is zeroed. Slowly move the force-measurer away from the box and watch the metal blade. Have your partner tell you when the box <u>just begins</u> to move. Read the force-measurer scale at this moment.

89. How much force was needed to <u>just start</u> the box moving?

_______________________________ newtons

Repeat this procedure several more times to be sure your first reading was correct.

90. What was the largest force you could apply before the box just started to move? _______________________________ newtons

5.4 qu This again is the same question you have not been able to answer up to this point. But now you might have something that will help you get an answer. What is it?
(1) The proctor
(2) The balloon elevator
(3) The double pan balance
(4) The force-measurer
(5) None will help
ca 4
ty Right
wa 1
ty The proctor will help when needed but he can't measure the force any better than you can. Try again.
wb 2
ty There isn't a force measuring scale on it. And besides, remember all the variables in using it. Try again.
wb 3
ty You are getting close, but there is something better to use with the box. Try again.
wb 5
ty Oh yes there is. Try again.
un Type the number of the answer only

5.5 qu If the slide projector is not on, turn it on and go to slide number 42, Figure 1. Type the time when you have it displayed. (Note: slide number 42 was a 35 mm kodachrome transparency of Figure 33 on the opposite page.)
ca 0

5.5a qu Good, check again to see that it is Figure 1. Now set up your force-measurer as shown in the slide. Is the card labeled "newtons" clipped in place and the metal blade (the heavy one) zeroed? (Type yes or no)
ca yes
ty O.K. Let's get to work then . Call the proctor.
wa No
ty Get it ready then and type yes when the card is in place and the blade is zeroed. Then call the proctor.
un Just type either yes or no.

5.6 qu You will slowly move the force-measurer away from the box and watch the metal blade. The proctor will tell you when the box just begins to move. Read the force-measurer scale at that moment. In Section 5.1 in your text record how much force was needed to just start the box moving. Follow the instructions in the text and be sure to answer both questions. Type in the time when you finish.
ca

91. Why did the box not begin to move as soon as any force was applied to it? ______________________

Something prevented the box from moving even though a force was present. This "something" has to be called a force under the definitions we have been using. We have already found in a previous chapter that forces cause change in motion.

CAI TEXT

5.7 Turn off the slide projector. (5 sec. pause)

qu Why did the box not begin to move as soon as you started to apply a force on it?

(1) Something prevented it form moving even though a force was present.

(2) There was a drag so the force applied had to overcome the drag before the box could move.

(3) The force of friction prevented movement until the pulling force was greater than the friction force.

(4) All of the above are good answers.

(5) None of the above is a good answer.

ca 4
ty Good
wa 1
ty True-- you picked the best answer, but some others are also possible answers. Type the number 4.
wa 2
wb 3
ty True-- but others are correct, too. Type 4.
wa 5
ty Wrong, try again.
un Type one number only 1,2,3,4, or 5.

5.8 qu In the following 3 questions, fill in the blank by typing the number of the correct alternative given here.

(1) direction
(2) friction
(3) motion
(4) drag
(5) a force

Something prevented the box form moving even though ____was present.

ca 5
ty Correct
wa 2
wb 4
ty You are too specific. (Hint: Friction or drag is ____.) Try again
wa 1
wb 3
ty No. Try again.
un Type a number, as directed above.

5.9 qu This "something" has to be colled a force under the definitions we have been using. We have already found in a previous chapter that forces cause change in ______. (Select the answer from the list in the last question and type its number.)

ca 3
ty Excellent
wa 1
wb2
wb 4
wb 5
ty Wrong, Try again.
un Type a number 1,2,3,4, or 5. Try again.

TEXTBOOK

Since the rate of motion of the box changes, this "something" must be a force. We will refer to this force as the <u>force</u> <u>of</u> <u>friction</u>.

In studying the force of friction, you will use one of the scientist's most important tools -- the experiment. You have already used the word "experiment" several times. Until now you have not thought very carefully about what it means. You now have the opportunity to find out what experiments are. You will do this by actually doing an experiment that is designed to tell you more about the force of friction.

Imagine that you have an empty red wastebasket, and a green wastebasket full of wooden blocks in front of you on the floor.

92. Which basket do you think would be the most difficult to slide along the floor? (That is, which would have more force of friction acting on it?)

____

5.10 qu Since the rate of motion of the box changes, this "something" must be a force. We refer to this force as the force of ____ (Select your answer from the previous list.)
ca 2
ty Very good
wa 1
3
5
ty No, try again.
wa 4
ty There is a better choice. Try again.
un Type a number for the choice you want, as directed above.

5.11 qu In studying the force of friction, you will use one of the scientist's most important tools -- the ________.
(1) atomic bomb
(2) hammer
(3) elephant gun
(4) experiment
ca 4
ty Sure
wa 1
ty Boom, You flunk! Try again.
wa 2
ty Ouch -- pick something better
wa 3
ty You ought to be shot. Try again.
un Pick a number and type it.

5.12 qu You have already used the word "experiment" several times. Until now you have not thought very carefully about what it means. You now have the opportunity to find out what experiments are. You will do this by actually doing an experiment that is designed to tell you more about the force of friction.

Imagine that you have an empty red wastebasket and a green wastebasket full of wooden blocks out on the cement sidewalk.

Which basket do you think would be the most difficult to slide along the sidewalk? (That is, which would have more force of friction acting on it?)
Read All the answers before picking the best one.
(1) the red wastebasket
(2) the green wastebasket
(3) the heavier one
(4) the one with the rougher bottom
ca 2
cb 3
cb 4
ty Any one of the answers 2, 3, and 4 could be correct. Answer 2 really isn't really that good though, since we know color isn't related to friction. We did not have to experiment to find this out.
wa 1
ty Try again after rereading the question.
un Type the number of the correct answer. Try again.

TEXTBOOK

You probably answered the last question by saying "the heavier one." However, you might have said "the one with the rougher bottom." You might even have said "the red one," but most people would easily see that color isn't related to friction. They do not have to experiment to find this out.

Scientists experiment when they are not sure which variables are the important ones. Even when they find it necessary to experiment, they often guess ahead of time at the result. Such a guess is sometimes called an "<u>hypothesis</u>." If your guess was a good one, your hypothesis was that "the weight of the blocks was what made one basket more difficult to slide than the other."

As you will soon see, knowing the variables in a situation is very important in setting up an experiment. An hypothesis, because it helps identify variables, can be very important. We will have more to say about the value of hypotheses (the plural form of "hypothesis") later.

93. Describe how you would find out if your hypothesis about the weight of the blocks was correct?

____

____

CAI TEXT

5.13 qu Scientists <u>experiment</u> when they are not sure which <u>variables</u> are the important ones. Even when they find it necessary to experiment, they often guess ahead of time at the results. Such a guess is sometimes called an <u>hypothesis</u>.

"The weight of the blocks was what made one basket more difficult to slide than the other," is an example of a good ____________________.

(1) experiment
(2) variable
(3) hypothesis

ca 3
ty Good
wa 1
ty No. The sentence tells about a thought, not an action. Try again.
wa 2
ty No -- the sentence describes a thought about variables but is not a variable itself. Try again.
un Type either 1, 2, or 3.

5.14 qu As you will soon see, knowing the variables in a situation is very important in setting up an experiment. An hypothesis, because it helps identify variables, can be very important. We will have more to say about the value of hypotheses (the plural form of "hypothesis") later.

How would you find out if the hypothesis about the weight of the blocks was correct?

(1) think about the problem and predict an answer.
(2) try it out to see
(3) ask for the opinions of others.

ca 2
ty Right -- design an experiment and try it.
wa 1
wb 3
ty Try again -- hint -- <u>experiment</u>.
un Type 1, 2, or 3.

APPENDIX B

Sample of IBM 1400 System
Student Printout Material

The CAI Text and Responses as Seen by the Student

"EXPERIMENTING" WITH DRAG

You have probably concluded by now that there must be something special about the force that you have been calling "drag." It keeps coming up again and again. --- involves what is probably the most important force known -- the force of friction.

Take a look at the previous sentence. Look for a four letter word that means the same thing as friction. It stands out like a sore thumb. --- Type it.

drag

Right.

Friction is so important that we will devote the entire chapter to study it. As you study friction you will also be learning about one of the most important tools of science -- the experiment.

To start your study, check to see that you have the box from the balloon elevator in your equipment. Attach a string to the box. Now put two metal cubes in it, place it on the table, and pull on the string until the box just begins to move. Type the time when you finish.

411

How much force was needed to start the box moving?

1. 5 newtons
2. 500 newtons
3. not very much force
4. quite a bit of force
5. I can't tell for sure

3

Perhaps it isn't much compared to that for pulling an elephant but it's a lot compared to pulling a flea. Try again.

4

It's quite a bit compared to pulling a flea but not much compared to the force needed to pull an elephant. Try again.

5

Right. That's probably the best answer.

This again is the same question you have not been able to answer up to this point. But now you might have something that will help you get an answer. What is it?

1. the proctor
2. the balloon elevator
3. the double pan balance
4. the force-measurer
5. none will help

3

You are getting close, but there is something better to use with the box. Try again.

4

Right.

If the slide projector is not on, turn it on and go to slide number 42, Figure 1. Type the time when you have it displayed.

416

Good, check again to see that it is Figure 1. Now set up your force-measurer as shown in the slide. Is the card labeled "newtons" clipped in place and the metal blade (the heavy one) zeroed? (Type yes or no)

yes

O.K. Let's get to work then. Call the proctor.

You will slowly move the force-measurer away from the box and watch the metal blade. The proctor will tell you when the box just begins to move. Read the force-measurer scale at that moment. In Section 5.1 in your text record how much force was needed to just start the box moving. Follow the instructions in the text and be sure to answer both questions. Type in the time when you finish.

420

Turn off the slide projector.

Why did the box not begin to move as soon as you started to apply a force on it?

1. something prevented it from moving even though a force was present
2. there was a drag so the force applied had to overcome the drag before the box could move.
3. the force of friction prevented movement until the pulling force was greater than the friction force.
4. all of the above are good answers
5. none of the above is a good answer.

4

Good.

In the following 3 questions, fill in the blank by typing the number of the correct alternative given here.

1. direction
2. friction
3. motion
4. drag
5. a force

Something prevented the box from moving even though _____ was present.

5

Correct.

This "something" has to be called a force under the definitions we have been using. We have already found in a previous chapter that forces cause change in _____. (Select the answer from the list in the last question and type its number.)

3

Excellent

5.10

Since the rate of motion of the box changes, this "something" must be a force. We refer to this force as the force of _____ (Select your answer from the previous list.)

2

Very good

In studying the force of friction, you will use one of the scientist's most important tools -- the ___________.

1. atomic bomb
2. hammer
3. elephant gun
4. experiment

4

Sure

You have already used the word "experiment" several times. Until now you have not thought very carefully about what it means. You now have the opportunity to find out what experiments are. You will do this by actually doing an experiment that is designed to tell you more about the force of friction.

Imagine that you have an empty redwastebasket, and a green wastebasket full of wooden blocks out on the cement sidewalk.

Which basket do you think would be the most difficult to slide along the sidewalk? (That is which would have more force of friction acting on it?)

Read All the answers before picking the best one.

1. the red wastebasket
2. the green wastebasket
3. the heavier one
4. the one with the rougher bottom

3

Any one of the answers 2, 3, and 4 could be correct. Answer 2 isn't really that good though, since we know color isn't related to friction. We did not have to experiment to find this out.

Scientists experiment when they are not sure which variables are the important ones. Even when they find it necessary to experiment, they often guess ahead of time at the results. Such a guess is sometimes called an hypothesis.

"The weight of the blocks was what made one basket more difficult to slide than the other," is an example of a good ______________________.

1. experiment
2. variable
3. hypothesis

3

Good.

As you will soon see, knowing the variables in a situation is very important in setting up an experiment. An hypothesis, because it helps identify variables, can be very important. We will have more to say about the value of hypotheses (the plural form of "hypothesis") later.

How would you find out if the hypothesis about the weight of the blocks was correct?

1. think about the problem and predict an answer.
2. try it out to see.
3. ask for the opinions of others

Right -- design an experiment and try it.

Now you are ready to begin setting up the experiment. You will start with the hypothesis that it was the weight of the blocks in the wastebasket that made it more difficult to start it sliding. Rather than just talk about blocks and wastebaskets, you should state the hypothesis very <u>broadly</u>.

Appendix C

Comparison of CAI and Field Trird Year Trial Text Materials

5 Experimenting with Drag

Suppose your face puffed up and broke out in blotches after eating a meal. And suppose this happened only now and then. You might guess that you had an allergy -- that you were sensitive to certain foods. You would want to find out which food or foods caused your face to blotch and swell.

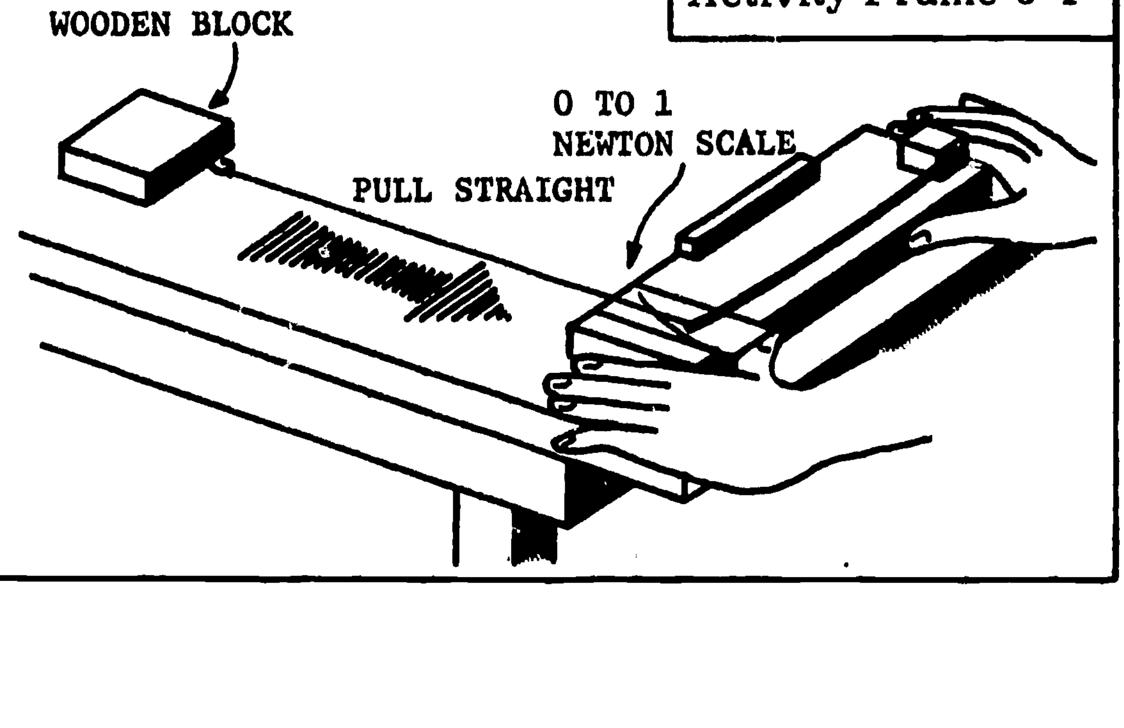
You might find out by experimenting in your own home. Immediately after an attack, you could list every item of food you had just eaten. Then you could repeat the same meal on other days, changing only one item (one variable) each day. For example, on Monday you could eat the same meat, vegetables, and dessert but drink a different liquid. If your face still puffed up, you might assume that the liquid was not responsible. On Tuesday, you could repeat the meal, changing only the dessert. On Wednesday, you could change a vegetable, on Thursday another vegetable, and on Friday the meat. If your experiment was carefully controlled -- the food was cooked in the same way and you ate the same amounts, you might be able to discover which food brought on the attacks.

Experiments are one of the most rewarding tools of science. They are rewarding, that is, when they are done properly. You will have a chance now to see what is meant by proper procedure. You are about to do an experiment with the force you call "drag." As you know, "drag" is what scientists call friction (frik-shun). Let's find out more about it. Pick out a classmate to help you and obtain the following equipment from the supply area:

1 small wooden block with hook
3 sinkers
1 piece of thread (tie a paper-clip hook on each end)
1 force measurer with thin blade
1 surface board with four different surfaces

Activity Frame 5-1

Arrange your equipment as shown, with scale attached and blade at zero. Slowly move the force measurer away, keeping your eyes on the scale. Your partner will tell you when the block just begins to move. Read the scale at that instant. Practice several times.



CAI TEXT

01 CHAPTER 5 EXPERIMENTING WITH DRAG

Suppose your face puffed up and broke out in blotches after eating a meal. And suppose this happened only now and then. You might guess that you had an allergy -- that you were sensitive to certain foods. You would want to find out which food or foods caused your face to blotch and swell.

02 You might find out by experimenting in your own home. Immediately after an attack, you could list every item of food you had just eaten. Then you could repeat the same meal on other days, changing only one item (one variable) each day. For example, on Monday you could eat the same meat, vegetables, and dessert but drink a different liquid. If your face still puffed up, you might assume that the liquid was not responsible.

03 On Tuesday, you could repeat the meal, changing only the dessert: On Wednesday, you could change a vegetable, on Thursday another vegetable, and on Friday the meat. If your experiment was carefully controlled -- the food was cooked in same way and you ate the same amounts, you might be able to discover which food brought on the attacks.

04 Experiments are one of the most rewarding tools of science. They are rewarding, that is, when they are done properly. You will have a chance now to see what is meant by proper procedure. You are about to do an experiment with the force you call "drag." As you know, "drag" is what scientists call <u>friction</u> (frik-shun). Let's find out more about it.

05 Pick out a classmate to help you and obtain the equipment from the supply area; listed in text section 5.1, and do Activity Frame 5-1. (Note: Activity Frame 5-1 in the student text was identical to the Activity Frame 5-1 on the opposite page.)

page 5-2

● 5-1. How much force was needed to just start the block moving? ____________ newtons

Pull the block several more times to be sure your first reading was correct.

● 5-2. What was the largest force you could apply before the block started to move? __________ newtons

● 5-3. Why didn't the block begin to move as soon as any force was applied to it? ____________________________________

Something kept the block from moving even though a force was acting on it. This "something" caused the force-measurer blade to bend, so it must be a force. You know of this force as "drag" or friction.

● 5-4. Why "must" friction be a force? (Hint -- how did you define "force?") ____

CAI TEXT

06 5-1. How much force was needed to just start the block moving? ___ newtons Pull the block several times to make sure first reading was correct. Type your answer using decimal numbers.

07 5-2 . What was the largest force you could apply before the block started to move? __________newtons

08 5-3. Why didn't the block begin to move as soon as any force was applied to it? Write your answer in text section 5.2.

Text Section 5.2

5-3. Why didn't the block begin to move as soon as any force was applied to it? There was more force on the block

Return to terminal

09 Something kept the block from moving even though a force was acting on it. This "something" caused the force-measurer blade to bend, so it must be a force. You know of this force as "drag" or friction.

10 5-4. Why "must" friction be a force? (Hint -- how did you define "force?") Write your answer in text Section 5.3.

Text Section 5.3

5-4 Why "must" friction be a force? (Hint -- how did you define "force?") Because it makes things move.

Return to terminal

EXPERIMENTING WITH FRICTION

In the next set of activities, you will try to find out what variables affect the amount of friction in a situation. To make the problem clearer, think back to when you moved the block with the force measurer.

● 5-5. List as many things as you can that affected how much the blade bent as you moved the block along the table. ______

______

Now imagine that you have an empty red wastebasket and a green wastebasket full of wooden blocks in front of you on the floor.

● 5-6. Which basket do you think would be harder to slide along the floor? (That is, which would have more force of friction acting on it?) ______

● 5-7. Why would it be the harder basket to slide? ______

______

You probably answered the last question by saying "because it is heavier." However, you might have answered "because it has a rougher bottom." You might even have said "because it is green (or red)." But most people realize that color doesn't affect friction.

CAI TEXT

11 EXPERIMENTING WITH FRICTION In the next set of activities, you will try to find out what variables affect the amount of friction in a situation. To make the problem clearer, think back to when you moved the block with the force measurer.

12 5-5. List as many things as you can that affected how much the blade bent as you moved the block along the table. Write your answer in text section 5.4

Text Section 5.4

5-5. List as many things as you can that affected how much the blade bent as you moved the block along the table.
drag-weight-speed

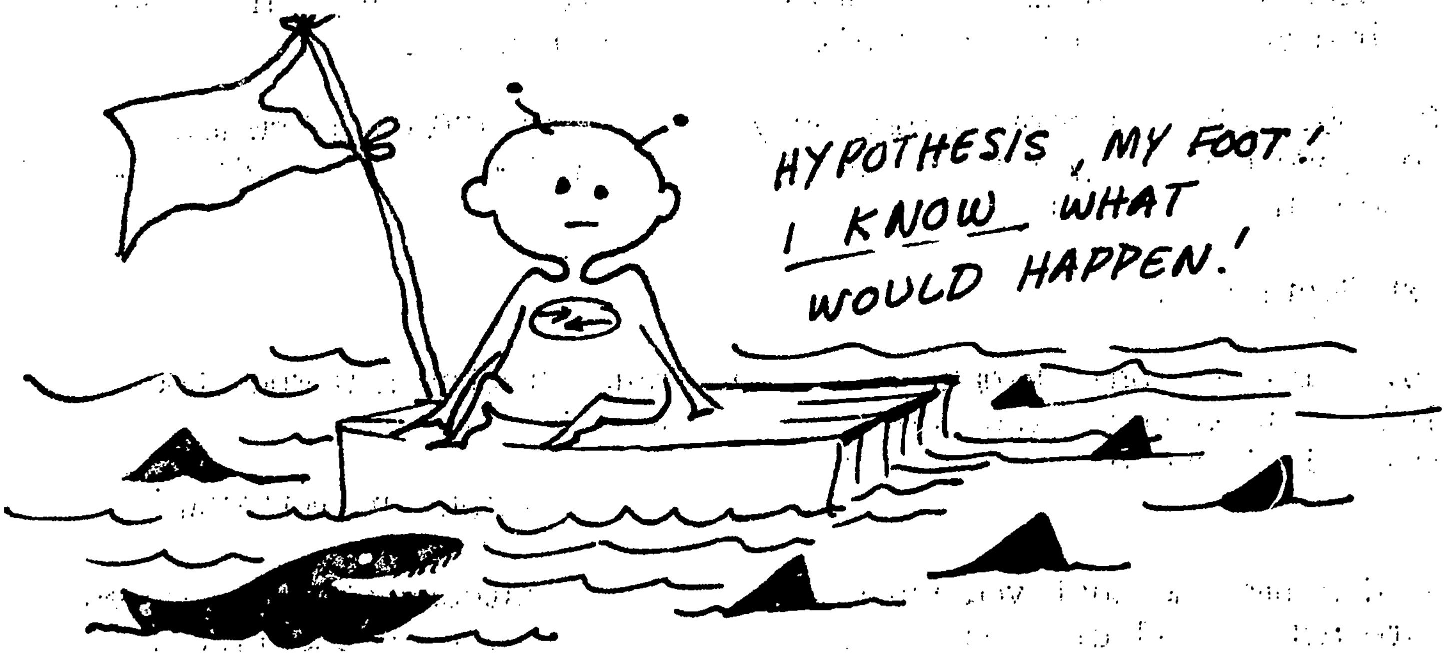
RETURN TO TERMINAL

13 Now imagine that you have an empty red wastebasket and a green wastebasket full of wooden blocks in front of you on the floor. 5-6. Which basket do you think would be harder to slide along the floor. (That is, which would have more force of friction acting on it?)

1 the red wastebasket
2 the green wastebasket
3 I cannot tell from what is given

14 5-7. Why would it be the harder basket to slide?

15 You probably answered the last question by saying "because it is heavier." However, you might have answered "because it has a rougher bottom." You might even have said "because it is green (or red)." But most people realize that color doesn't affect friction.



Scientists do experiments to find out which variables are the important ones in a situation or to discover the effect of variables. Quite often they try to guess the answer to their question before they start an experiment. An explanation guessed in advance is sometimes called an hypothesis (high-pa-theh-sis). Your answer to Question 5-7 was really an hypothesis. You guessed which basket was harder to move. Your explanation was only a guess, too.

5-8. How could you test your hypothesis as to which basket would be harder to move? ______________________________
____
____

CAI TEXT

16 Scientists do experiments to find out which variables are the important ones in a situation or to discover the effect of variables. Quite often they try to guess the answer to their question before they start an experiment.

17 An explanation guessed in advance is sometimes called an <u>hypothesis</u> (high-pa-theh-sis). Your answer to Question 5-7 was <u>really</u> an hypothesis. You guessed which basket was harder to move. Your explanation was only a guess, too.

18 5-8. How could you test your hypothesis as to which basket would be harder to move?

APPENDIX D

ENTER AND PROCESS IDENTIFIER CODES

The ten-digit ISCS EPID code included eight fields as shown in the diagram below:

Chapter	Page	Content	Process	Track	Question Code	Question Number	Sequence Number
1	2	3	4	5	6	7-8	9-10

Descriptions of each field

1. Chapter Alphanumeric code, a-z, corresponding to chapter numbers 1-26.

2. Page Alphanumeric code, a-z, corresponding to page numbers 1-26.

3. Content Alphanumeric code, a-z and 1-9, for identification of the frame.

4. Process Alphanumeric code a-z, 1-9, for identification of the scientific process involved in the frame. The representation is the same for both seventh and eighth grades.

5. Track Alphanumeric code, corresponding to the following key:
   m mainline
   e, i, x, excursion

6. Question Code Each frame contains an alphanumeric code to allow for sorting on questions.
   a no question in frame, only the presentation of information
   x question in the computer program to be answered at the terminal
   t, y, z, question, with answer to be written in student text

7-8. Question Number Two character numeric code, which corresponds to the question number in the classroom text. If there is no question, the code is 00.

9-10. Sequence Number Two character numeric code, 01-99, corresponding to the frame sequence number. The first frame of each segment is 01, the next 02, etc. If there are more than 99 frames, the code recycles, starting with 01.