1 OF 2

ED 089 786

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MICROCOPY RESOLUTION TEST CHART

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ABSTRACT

A report is given of the activities carried out during the first seven months of a computer-assisted instruction (CAI) project at Pennsylvania State University, begun in May 1965. The project's objectives are listed as: 1) to determine how CAI can be used to present core courses in technical education; 2) to prepare CAI materials in technical mathematics, engineering science, and communication skills for post-secondary students; 3) to train individuals to prepare CAI materials and to research computer applications in technical education; and 4) to disseminate information about CAI. The first section of the report deals with the physical facilities provided by the University and the equipment configuration used, while the following segment describes the initial course development activities in the technical education subjects. Brief reports of research findings are presented in the third section and the final part of the report consists of an appendix which provides an evaluative review of CAI efforts throughout the country. (Author/PB)

THE PENNSYLVANIA STATE UNIVERSITY

Computer Assisted Instruction Laboratory
University Park, Pennsylvania

Semi-Annual Progress Report

EXPERIMENTATION WITH COMPUTER-ASSISTED INSTRUCTION IN TECHNICAL EDUCATION

Project No. 5-85-074

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December 31, 1965

INTRODUCTION

This report spans the first seven months of the operation of the computer assisted instruction (CAI) project and is designed to show Penn State University's stewardship of its own resources and the federal funds awarded to it under the provisions of Section 4(c) of the Vocational Education Act of 1963.

Briefly, the objectives of the original proposal were as follows: (1) To evaluate the articulation of computer-assisted instruction with other educational strategies and, by means of careful experimentation, determine optimum ways of presenting core courses in technical education curricula; (2) to prepare curriculum materials for computer presentation with emphasis on the instruction of post-high school students in technical mathematics, engineering science, and communication skills; (3) to train an interdisciplinary group of individuals to prepare course materials and to do research on computer applications in technical education; (4) to disseminate the information and evidence concerning the innovation of CAI and its application to occupational education.

Progress has been made toward all of these objectives and the evidence is detailed in the following report. The first section deals with the physical facilities provided by the University and the equipment configuration in operation during the past seven months. The second section concerns the initial course development activities in technical education subjects. Brief reports of research findings are presented in the third section, and the fourth part is an appendix consisting of a separate evaluative review of CAI efforts throughout the country.

PHYSICAL FACILITIES AND EQUIPMENT

Physical Facilities. The project was begun by using temporarily converted classrooms for office space, and music education practice rooms for the location of student teaching terminals. A large room, 45 ft. x 45 ft., has since been remodeled and partially occupied. The remodeled space has been designed to accommodate ten professional staff members, eight graduate assistants, five CAI technicians, and four student terminals. From its own resources, the University has made available $5,500 for new office furniture and equipment, and $5,100 for the installation of air conditioning and associated electrical controls in the space occupied by the four heat-generating student terminals. Delays were experienced in obtaining delivery on the air conditioning controls and as a consequence the whole remodeling job has been temporarily suspended Anticipated completion, however, is January, 1966

Equipment Since July 1, 1965, the two student terminals in the CAI Lab have been connected by means of dedicated long distance telephone lines to the IBM 7010-1448 computer configuration at the T. J. Watson Research Center, IBM Corporation, Yorktown Heights, New York. For this service, we are under contract with IBM until June 30, 1966. The service includes not only 64 hours of terminal time weekly, but course listings from the compiler and summarized student records taken from log tapes.

Delivery was expected in October of four new IBM 1050 communications terminals with improved audio-visual components, but manufacture has been delayed. Installation of this equipment replacing the presently used two "bench-built" units, is anticipated early in January. Orders have been placed for the additional four terminals to be installed in Williamsport and in Altoona by July 1, 1966.

COURSE DEVELOPMENT IN TECHNICAL EDUCATION

Preparation of three courses has begun for content presentation via CAI by means of a language known as Coursewriter Although a complete description of the language is beyond the scope of this report, a summary of the functions of each of the operation codes in current use is given below. A complete manual for the Coursewriter language is in preparation as a part of the Laboratory's current project on the development of four college level courses with support from the Bureau of Research, U.S.O E.[1]

Summary of Coursewriter operation codes:

rd - Computer types text and waits for the student to signal completion. Commonly used to display a reading assignment to a student.

qu - Computer types text and waits for student to respond Commonly used to display questions or problems to a student.

ca - Correct answer to be stored in memory for comparison with a student's answer

cb - Similar to ca, is used to identify one of a set of alternative correct answers when the subsequent action is the same regardless of which answer in the set is given by the student

wa - Wrong answer to be compared with student's answer

wb - Similar to wa, is used to identify one of a set of wrong answers when subsequent action is the same for all answers in the set

un - Text to be typed if the student's answer is not one of the specified correct or wrong answers

ty - Computer types text and continues without waiting for a response from the student

br - Branch - alters the sequence of execution Branches can be unconditional, i.e., not contingent upon a specific wrong or correct answer, or conditional upon the number of errors made by a student on a previous series of questions.

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[1] " Development and Presentation of Four Different College Courses by Compute. .. :processing" Interim Report, Project #OE 4-16-010, June, 1965, Computer Assisted Instruction Laboratory, Penn State University, University Park, Pa.

xl - Time limit - maximum number of seconds to wait for student to respond may be specified following this code.

ad - Add a quantity or the contents of a counter to a counter. Commonly used for accumulating a student s errors and response times The contents of a counter may be tested by means of a conditional branch, and the course sequence altered depending on the contents of a student's counter

nx - Instructs the computer "if not the preceding then do the following." It is used prior to each partial answer function and initiates no interaction with the student

fn - The fn statement is used to "call in" or activate a function.

fn slide//n - Used to present a slide; n represents the number of the slide to be displayed Up to 80 slides may be displayed from a single tray

fn slide//nx - This function will seek and position slide n, but will not show the slide until a display slide function (see preceding function) occurs in the program

fn dx//n - This function will display the contents of an x-counter to the student specifying time The n refers to the number of the x-counter to be displayed.

fn wait// - This function allows the author to delay the program before continuing execution

fn tape//n - This function will play tape recording number n.

fn tape//nx - This function will seek and position tape recording number n, but will not play the recording until a tape play function (see preceding function) occurs in the program

fn dc//cn - The display counter function is used to display the contents of a numerical counter to the student The n refers to the number of the c counter to be displayed

comment - The comment statement, which is not presented to the student, enables the author to record descriptive remarks. The remarks are for the author's information and do not affect the operation of the program.

ld - Load enables an author to clear a counter and load it in one instruction

ic//ab//c - The initial character function designates a number of initial characters which are compared with a subsequent ca or wa. If the specified initial characters in the student's response are matched with those in the ca or wa, the function is satisfied The function also allows for the author to specify that certain positions of the responses are to be considered as irrelevant

fn pa0//ab//c//d - The partial answer zero function is used to process answers which are misspelled or partially correct. The function compares segments of the student's answer with segments of the ca or wa If the number of characters in the matched segments equals or exceeds the per cent specified by the author, the function is satisfied If the author so indicates, the matched portions are typed in black and the unmatched portions may be typed in red or a "-" may be inserted for each unmatched character A function programmed as pa0//64r//50//c9 specifies that the student's answer is to be checked first in strings of 6 characters and then in strings of 4 characters. If 50 per cent of the characters are matched, the matched portions will be typed in black and the unmatched portions will be typed in red The percentage actually matched is stored in counter 9.

fn limits - The limits function tests whether the numerical response to a student's response is within specified limits.

fn sb///a//b///c - The save and branch function causes the program to branch to a reference location (subroutine). The function also specifies the location to which control will be branched upon completion of the subroutine

fn rb - The return branch function is used with the sb function. The return branch function causes the control to branch from the subroutine to the address previously specified by the sb function

fn kw// - The key word function allows an author to specify one or more key words which must be matched in the student's answer. When the key word function is used in this form, the order that the key words appear in the student's response is not important. Also, the student's response may contain words not among the key words to be matched

fn kwo// - The key words - ordered function is similar to the key word function The function is satisfied only if the key words are contained in the student's response and match and are in the same order as those in the ca or wa.

fn kwi - The key words- initial function searches for key words in the order in which they are entered in the ca or wa If the kwi function finds a word in the student's response not contained in the ca or wa, the function is not satisfied.

fn kwio - The key words - initial and ordered function is combination of the kwi and kwo functions To be satisfied, the key words in the student's response must appear in the same order as in the ca or wa Also, the function will not be satisfied if the student's response contains any word not contained in the ca or wa

<u>fn</u> connect//a//b - The <u>connect</u> function allows an author to connect one course to another course.

<u>fn</u> irand//cn - The <u>pseudo-random integer</u> function places a pseudo-random integer in a numerical counter (c0-c9).

<u>CAI Technical Mathematics</u>

Joe K. Ritchey

The examination of technical mathematics curricula as preliminary to the development of a CAI course has included a review of the available texts in technical mathematics and some correspondence with mathematics instructors in technical institutes.

At the present time, we believe that a course encompassing the best elements of several texts and educational materials is the proper procedure. To accomplish this requires the writing of the material prior to the programing For example, in significant figures, research was conducted on the topic followed by the writing of a body of material. From this content, the <u>Coursewriter</u> program was prepared.

The technical mathematics curriculum embodied in the CAI course under preparation will include the following topics: linear equations, graphing, quadratic equations, exponents, roots, trigonometry, analytical geometry, simultaneous quadratic equations, binomial theorem, and calculus.

By design the first segments programed are common to both physics and mathematics instruction The common segments include the metric system, working with units, scientific notation, and significant figures.

A visit to the campus of the Williamsport Community College was conducted and one is being planned for the Altoona campus of Penn State's

Commonwealth system. The purpose of these visits was to establish a working relationship with the faculties of the institutions. During the visit to Williamsport, information was obtained concerning their mathematics program, and the department staff expressed much enthusiasm concerning their part in the CAI project

Recently a meeting to discuss CAI was conducted with Professors James B. Bartoo and Frank Kocher of The Pennsylvania State University mathematics department. During the meeting Professor Kocher presented outlines of Math 801, Math 802, and Math 803, which are to be reviewed in relationship to the computer program in technical mathematics. The meeting established a basis for a liaison between the CAI project and the mathematics department of Penn State.

A summary of the course segments and their content appears in Table 1.

Table 1

Course Segments Developed to Date
for Technical Mathematics

Course Segment Name	Topic	Author	No. of Coursewriter Instructions	Slides	No. of Tape Messages	Average Time for Student
ae physics	Significant Figures	Gilman	Not yet compiled	--	--	--
calc	Kinematics and Calculus	Gilman	240	9	9	1 hr.
sigfig1	Significant Figures	Logan	353	0	0	1 hr.
ab physics	Metric System	Gilman	1,127	3	0	2 hrs.

Sample Program

LABEL	OPR MODE	ARGUMENT
b-5	rd	
	fn	slide//002

Contents of Slide 002:

$$\vec{v} = \frac{s_1 - s_0}{t_1 - t_0} = \frac{\Delta s}{\Delta t} \qquad \text{Equation 2}$$

---

	fn	tape//9

Contents of Tape 9:

In calculus we are concerned with instantaneous velocity. This means that the time interval (t_1 - t_0) is made smaller and smaller until it approaches a value of zero.

---

	fn	tape//10x

*This operand positions tape 10 and also prevents the computer from prematurely asking the student the next question.**

	qu	
	ca	P
	cb	
	wa	R
	br	b-5
	un	TYPE P or R

---

*N B. All material in italics represents author's explanatory comments about the stored computer program.

The above sequence illustrates the display of a slide followed by a tape The student has the option of proceeding in the program or viewing the slide again and repeating the tape by typing : · R respectively.

qu As the time interval (delta t) of equation 2 becomes very small, it approaches a value of _______.

nx

fn kw//1

ca ,o,0, 0 , nothing, the axis

ty Correct As the time interval becomes smaller, it approaches zero.

The keyword 1 function processes as a correct answer, followed by the ty, any one of the responses between the delimiters of the ca. In this example, the comma is used as a delimiter.

nx

fn pa0//6421//75

wa infinity

ty Wrong As a quantity becomes smaller, it does not approach infinity. Try again.

The partial answer zero function was used to process the wa. The number 6421 designates how many adjoining characters must match before the string is considered correct. The 75 is the percentage (determined by the author) of characters in the wa which must be matched in the student's response to satisfy the function.

un The quantity (delta t) is becoming smaller and smaller. When something becomes very small, what number does it approach? Type your answer.

rd

fn slide//007x

rd The next slide contains two important definitions.

Press EOB.

fn slide//007

Contents of Slide 007:

DEFINITIONS:

a. The limit of $\frac{\Delta s}{\Delta t}$ as Δt approaches zero is called the derivative of s with respect to t.

b. The process of finding the derivative is called differentiation.

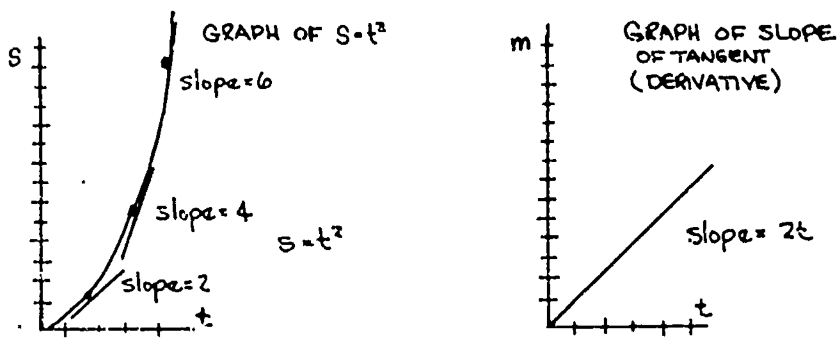
---

rd The geometric interpretation of the derivative is the slope of a line tangent to the curve. Slide 8 will show what this means. Press EOB.

rd

fn slide//008

Contents of Slide 008:



CAI Engineering Science

David A Gilman

The planning of the course in engineering science has included comprehensive examination of the engineering technology and physics curricula of many vocational institutions. Most of the available texts in technical physics have been reviewed

After investigating physics texts published for instruction of students enrolled in vocational courses, it was decided that none of these presented an adequate version of technical physics. Therefore, a course of study incorporating the best selected elements of several texts appears to be an optimum approach The writing and programing of such material is the task to which we are addressing ourselves. As soon as a good grasp of the content is obtained and a first course or major segment has been programed, we expect to produce experimental versions of the material in order to test specific hypotheses about CAI.

Because there is a certain amount of subject matter common to physics and mathematics, these areas were programed first. Presently, topics in scientific notation, the metric system, working with units, significant figures and kinematics have been programmed and are available for testing by student subjects. Also, a chapter explaining the relationship between physics and engineering has been programed and is available for computer presentation to students on a tryout basis. Short segments in magnetism and atomic energy have been written and are being tested.

The overall instructional strategy for CAI Engineering Science and Technical Mathematics is to begin with a common subject matter and branch into separate technically oriented mathematics and physics courses.

However, the separate courses are to be correlated, so that instruction in physics topics will have been preceded by the prerequisite mathematics for that topic.

The physics curriculum will include beginning material of mechanics, heat, matter, electricity, magnetics, electronics, modern physics, light, and sound.

Technological adaptations of physics knowledge will not be stressed to a great degree. Examination of curriculum materials and discussions with instructors developed diverse opinions as to whether physics at this level could best be taught by a discovery approach or by the traditional method of presenting facts and problem solving methods. It has been decided that a combination of these two methods would be the best approach. However, the structure of the science of physics is being emphasized and should provide a valid framework for learning fundamental concepts.

Visits have been made to Altoona and Williamsport campuses in an attempt to establish a working relationship with the science and mathematics faculties of these institutions. Also, information is being obtained from these teachers which will make the CAI instruction compatible with the conventional instruction of these respective institutions.

Numerous delays have been experienced in the development of course material. Some of these delays have been due to the time lost in the trial and error involved in setting up new operating procedures. Some delays have been due to the lack of understanding of some facets of Coursewriter language and the knowledge required regarding the operation of the computer based system.

The authors of the physics and mathematics courses are working together very closely in areas of instructional strategy and curriculum content.

A summary of the course segments in Engineering Science and their content appears in Table 2

Table 2

Course Segments Developed to Date for Engineering Science

Course Segment Name	Topic	Author	No of Coursewriter Instructions	Slides	No. of Tape Messages	Average Time for Student
aa physics	Introduction to Physics	Gilman	313	9	8	3/4 hr.
ac physics	Working with Units	Gilman	1014	9	1	2 hrs
ad physics	Scientific Notation	Ritchey	748	24	0	1 3/4 hrs.
atom	Atomic Energy	Gilman	872	20	15	2 hrs.
mag	Magnetism	Ritchey	416	12	7	3/4 hr.

As each topic is developed, different research possibilities are considered. For example, the segment on Working with Units has been written so that a branching program can be compared with a linear program. The segment on significant figures is being written so that a program utilizing computer instruction and displays can be compared with stand-alone computer instruction

The fact that Computer Assisted Instruction is new means that the adoption of techniques is being made by our staff almost daily in hardware utilization and teaching strategies. Many of these innovations may ultimately prove to advance the implementations of computer assisted instruction

Sample Program

LABEL OPR MODE ARGUMENT

ac-40

rd

fn slide//2

Contents of Slide 2:

Fractions

$$\frac{3}{4} \div \frac{5}{2} = \frac{3}{4} \times \frac{2}{5} = \frac{3}{\cancel{4}_{2}} \times \frac{\cancel{2}^{1}}{5} = 3/10$$

Units

$$12 \text{ cm} \div 4 \text{ sec} = {}^{3}\cancel{12} \text{ cm} \times \frac{1}{\cancel{4}_{1} \text{ sec}}$$

$$= 12 \text{ cm} \times \frac{1}{4 \text{ sec}} = 3 \text{ cm/sec}$$

---

rd Slide 2 shows two operations. The top of the slide shows division of a common fraction. The bottom half shows how units are divided. In both cases, you invert the divisor and multiply.

Slide shows similarity of method for dividing fractions and method for dividing quantities containing units. *

rd Sometimes the units cancel just as the fractions did. The next slide shows some cases of cancelling units.

---

*N. B. All material in italics represents author's explanatory comments about the stored computer program.

fn slide//3

Contents of Slide 3:

Example 1 (multiplication)

$$14\ \frac{cm}{\cancel{sec}} \times 3\ \cancel{sec} = 42\ cm$$

Example 2 (division)

$$3\ cm \div 4\ cm/sec = 3\ \cancel{cm} \times \frac{1\ sec}{4\ \cancel{cm}} = 3/4\ sec$$

Example 3 (division)

$$6\ cm/sec \div 2\ cm = \overset{3}{\cancel{6}}\ \frac{\cancel{cm}}{sec} \times \frac{1}{\underset{1}{\cancel{2}}\ \cancel{cm}} = 3\ /sec$$

Slide shows similarity of methods for cancelling in multiplication, and division of fractions and units.

rd In example 3, the units 3/1 x 1/sec, become 3/sec.

The unit /sec in the denominator is read per second.

The slash in a unit is always read per.

In the program the portions here underscored are typed out to the student in red which is used to emphasize concepts shown in slide 3.

ty Remember that the order of units makes no difference in multiplication. Thus gm-cm is the same as cm-gm.

rd However, in division, the order is very important.

30 miles/gallon is much different than 30 gallons/mile.

3 42

qu If a man drives a car at a speed of 60 mi/hr for four hours, what distance does he cover?

ca 240mi

```
br        ac-46//-1//c4
```

If the student has not readily understood the previous concept, he is branched to remedial instruction If he understands, he is branched to another topic in the program.

CAI Communications Skills

David C. Bjorkquist

The development of the CAI course in communications skills has followed a different route than that adopted for the technical mathematics and engineering science instructors. In this area it was decided to first build a program that would focus on the rapid improvement of spelling ability, to be followed, as time permits, with appropriate content in grammar, syntax, punctuation, and speech principles.

The purpose of this first segment of the CAI course in communications skills is to develop and evaluate a computer assisted program of instruction in remedial spelling for students preparing to be technicians. This computer program is planned to diagnose the spelling errors made by individual students and to branch students to remedial programs of instruction appropriate for the types of spelling errors made.

Students beginning the spelling program will complete an orientation which will introduce them to the Selectric typewriter, tape recorder, and photographic slide outputs of the computer. It will also acquaint them with the typewriter which they will use to respond and will try to impress upon them the importance of accurate spelling. Instruction in identifying word syllables and in listening for correct pronunciation will be included in the orientation.

The orientation will be followed by a diagnostic spelling test which will identify the types of spelling errors made by the individual. Words in the diagnostic test will be pronounced to the student via audio tape message, and he will respond by typing the word on the computer typewriter keyboard. Based on an analysis of the responses made by the student, the computer will branch those students needing remedial work to one or more of nine remedial programs

The diagnostic test will be made up of words involving these nine types of spelling problems

1. Plurals
2. Homonyms
3. Contractions and hyphenated words
4. Words with ie and ei combinations
5. Double consonants
6. Suffixes
7. E and y endings
8. Words requiring visual discriminations
9. "Demon" words

A student who misspells a portion of those words involving one of the types of spelling errors listed will be branched to the remedial program of instruction to correct that type of error.

After completion of the remedial program, the student will be tested to determine his degree of improvement. Failure to show marked improvement in correcting a type of spelling error will repeat the remedial program for the student.

Word lists for the diagnostic and remedial programs will be selected from graded spelling lists, themes written by students and from words used by technicians in their work. Emphasis will be placed on the inclusion of those words which are commonly used by technicians.

Following completion of the orientation, diagnostic test, and remedial programs, the student will then complete a proofreading exercise The purpose of this exercise will be to test the student's ability to recognize incorrectly spelled words in a printed page, to correct misspelled words and to emphasize the importance of proofreading for correct spelling Pages to be proofread will be presented to the student by means of a projected photographic transparency.

The conclusion of the program in spelling will be a posttest. This test will be made up of words randomly taken from the same word list as the diagnostic test

The specific objectives of the CAI spelling segment will be to develop the following abilities.

I. Ability to use a systematic word study approach
   A. Look, say, write
   B Break words into syllables
   C. Examine words for "trouble spots," i.e., silent letters, difficult vowel combinations, unphonetic sounds

II Ability to attack new words
   A Syllabication
   B Rootwords, add prefixes and suffixes
   C Compound and hyphenated words
   D Ability to discriminate
   E. Ability to use words in different form
   F Homonyms--words that sound alike but have different meanings and use

III Understanding of basic spelling rules
   A. Formation of plurals
   B Final e
   C Final y
   D Doubling the final consonant
   E qu
   F ie

IV. Ability to spell a specified number of words

A. General adult vocabulary list

B "Demon Words"--words which are consistently misspelled, defy rules

C. Specialized technical vocabulary list

V. Development of correct pronunciation

A. Hearing the word correctly

B. Saying the word (cannot check or measure this)

C. Use of dictionary for pronunciation

VI. Increased vocabulary

A. Understand meaning, use of word lists

B. Use of dictionary to find word meaning

C. Synonyms

D Understanding of word origins

VII Ability to use dictionary properly

A. Use dictionary for correct spelling

B Use dictionary for meaning

C Use dictionary for pronunciation

VIII. Improve attitude toward spelling

A Need for correct spelling

1 Ideas are presented clearly, are better understood

2 Reader receives better impression of writer

3 Courtesy to reader

B. Counteract defeatism

1. Can improve spelling ability with some concentration and effort

2. Provide successful experience

3. Reinforce correct response

In the development of the word lists and selecting words for the diagnostic test, the remedial branches, the proofreading exercise and the posttest, emphasis will be placed on commonly used words and technical words often used by technicians. The primary source of these words will be graded vocabulary lists prepared by authors in the field of spelling and words taken from written work of students in technical writing courses.

A review of the spelling literature has suggested that all spelling errors can be classified into the nine categories suggested as headings for remedial branches Words for each branch will be selected because of their appropriateness to that branch from the sources mentioned previously

The diagnostic and posttests will be designed to be of equal difficulty. This will allow for a gain score between the time of the diagnostic test given prior to the program and the posttest.

The <u>development of the programming technique</u> and teaching strategies used in the spelling segment will use the tutorial features of the computer and the field of knowledge about spelling instruction. Teaching approaches will be used which seem most appropriate to the kind of spelling problem being dealt with The total segment will be divided into parts concentrating on separate phases of spelling study thus allowing students to bypass those areas in which they do not need remedial work.

The typewriter, tape recorder and photographic slide outputs of the computer will be utilized For example, Horn[1] has suggested that poor spellers should be given practice in hearing sounds in words. The tape recorder output will be used to try to accomplish this. He also stated that the most frequent cause of poor spelling is poor study habits. The computer program will guide the student through a carefully planned study routine. Russell[2] reported that poor spellers failed to discriminate between word forms and between words similar in appearance. For this

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[1]E Horn, "Teaching Spelling: What Research Says to the Teacher." American Educational Research Association, Washington, D. C., 1954.

[2]D H Russell, "Characteristics of Good and Poor Spellers: A Diagnostic Study." Contributions to Education #727, Teachers College Columbia University, New York, 1937.

reason a remedial program in spelling discrimination has been included each phase of the program attempts will be made to identify and use the best ideas in programing of spelling materials

Evaluation of this spelling program will be used for two primary purposes (1) to improve the program of instruction, and (2) to determine the educational worth of the program Evaluation for the purpose of improving the spelling program will be centered in field testing of the program An important phase of this testing will be to develop a program appropriate for students in technical education Individual items of instruction will be altered and compared to try to improve the efficiency of the program Modes of presentation will be compared to determine the most effective way of using the computer in programing.

By use of pretests and posttests we will have some measure of spelling gains made by students A measure of retention will also be used Student gains and retentions must also be evaluated in terms of the amount of time necessary for achievement Individual remedial programs will be examined to determine how useful they are and how effective they have been in improving spelling

Sample Program

The following is a short segment of a remedial program designed to teach the use of i and e in spelling

LABEL	OPR MODE	ARGUMENT
ie6	rd	In most words ie are written as in diet There are some exceptions as in weigh The ei produce the sound of a Remember i before e except after c -- usually Press the EOB key to proceed

qu	Fill in the missing word. The plane crashed in a wheat f_____

This is programed to accept student response incorporating the required correct answer; i e , field or fields, etc.

nx	
fn	kw//1
ca	$field$
ty	Good
nx	
fn	kw//1
wa	$feild$
ty	i before e Type the word again.
un	The farmer plowed his f_____d
qu	i before e except after c. Receive; per-----. Type the entire word
nx	
fn	kw//1
ca	$perceive$
ty	Correct--perceive
nx	
fn	kw//1
wa	$percieve$
ty	Notice the c Type again.
un	Type perceive
qu	Fill in the missing letters and type the words ach--ve, gr--f, rel--ve

nx .

fn kw//3f

This key word feedback will type the entire ca substituting dashes for unmatched sequences in the order of their occurrence.

ca $$achieve$$grief$$relieve$$

A double delimiter, the two dollar symbols arbitrarily chosen by the author, are used here so that correct responses and forms are typed out to the student.

un Type achieve, grief, relieve.

qu Temporary end of course Sign off or type start

to begin again

ca start

br start

At the option of the student, he will be able to branch to beginning of course or sign off.

PRELIMINARY RESEARCH FINDINGS

Scrambled versus Ordered Course Sequencing in Computer-Assisted Instruction. Experiment I

Kenneth H. Wodtke

The ordered or "logical" sequencing of learning materials has been mentioned frequently as one of the primary advantages of programed instruction (Glaser, 1961) More recently investigators have attempted to utilize the decision logic of computers to arrange and present carefully sequenced instructional materials to students (Wodtke et al., 1965; Braunfeld, 1964; Stolurow and Davis, 1963) Although many instructional programs have been developed on the assumption that careful content sequencing facilitates student learning, the results of a number of empirical investigations have been inconclusive. Some of these studies report superior learning for carefully organized instructional programs (Evans, 1960; Stolurow, 1964), while others report either no differences between scrambled and ordered presentation conditions (Roe, Case, and Roe, 1962; Levin and Baker, 1963), or differences favoring the scrambled sequence condition (Hamilton, 1964) The question of the importance of careful sequencing or conceptual organization of instructional programs is particularly important in the context of computer-assisted instruction (hereafter referred to as CAI), which provides a high degree of flexibility in the planning, sequencing, and organization of course materials To maximize the potential of CAI, unambiguous answers to questions concerning course sequencing must be obtained

The following explanations may account for the contradictory results obtained in studies of the effects of scrambled versus ordered sequencing on student learning.

1) The effects of program sequence may interact with one or more dimensions of the learning task An examination of the programs used in a number

of studies reveals great variability in the subject matter content of the programs used Programs containing many interrelating concepts may require more careful sequencing than programs which teach a set of relatively discrete facts Examples of program content containing few sequential dependencies might be vocabulary, knowledge of terms, and anatomy. On the other hand, performance on a program containing relationships between concepts and the understanding and application of principles may be detrimentally affected by scrambled presentation of the material. In addition to the content of the material, sequencing may also interact with task difficulty, size of step, length of the program, and other similar variables Many of the programs used in previous studies have been relatively short, small-step, linear programs. One might expect logical sequencing to be less important in short, small-step, linear programs than in the long, relatively difficult, branching programs which are more typical in CAI In short, in small-step, linear programs, the student may be able to conceptually reorganize the scrambled material on his own

2) The effects of program sequence may interact with student individual difference variables One might expect the effects of content sequencing to be dependent upon the abilities, past achievements, and in-put behaviors of the learners For example, one might predict an interaction between student verbal ability and sequencing, indicating that the students of lower aptitude are more detrimentally affected by scrambled sequencing than the high-aptitude students In commenting on studies of the sequential properties of instructional programs, A A. Lumsdaine (1963) has emphasized the importance of the susceptibility of stimulus materials to the utilization of verbal mediating responses Some students may provide their own conceptual organization to a scrambled program by linking together varied parts of a scrambled sequence of items with verbal

mediators Students with high-verbal ability, or with extensive experience in subject matter areas related to the content of the programed materials, might not be adversely effected by scrambled sequencing of course materials

3) Previous investigations have sometimes failed to report evidence on the effectiveness of the "logically" ordered programed materials If the so-called "ordered" program in an experiment is actually not very effective in facilitating student learning, it is very difficult to obtain differences in learning when the sequence of the program is scrambled. In such a situation, the experimental comparisons essentially amount to comparing one ineffective program with another ineffective program

4) The effects of program scrambling may depend on the kinds of learning outcomes measured in the experiment For example, the recall of factual information may not be as impaired by item scrambling as would understanding or transfer of the material to new problem situations.

5) In some earlier studies, the assumption was made that the students had "zero" knowledge in the subject matter of the instructional program; and on this basis, a pretest was omitted Mager and Clark (1963) have pointed out that the assumption of "zero" knowledge in a subject matter area is highly untenable for adult and college populations In view of Mager and Clark's results, and considering the inconclusiveness of the findings of earlier studies of sequencing, the use of a pretest control for the amount of previous student learning would seem to be essential

Experiment I

This is the first in a series of investigations of the effects of course sequencing in CAI The primary purpose of the first experiment was to investigate the interaction between student aptitude and scrambled versus ordered sequencing of instruction In contrast to earlier investigations, the present study employed a fairly lengthy instructional program of considerable difficulty for the average college student. The material used involved the learning of principles, mathematical problem solving, and contained a large number of sequential dependencies among the concepts taught. The specific objectives and predictions of the experiment were as follows:

a) To determine under what conditions careful sequencing of instructional programs "make a difference" in student learning within the context of computer-assisted instruction. Following appropriate hypothesis tests, it was predicted that scrambled item sequencing would have a detrimental effect on student learning in a relatively lengthy, difficult program containing many sequential dependencies among concepts, e. g., when the mastery of some concepts and principles are prerequisite to the mastery of other concepts and principles.

b) To determine whether scrambled as compared to ordered item sequences have a differential effect on students of high- as compared to low-verbal aptitude. An aptitude by sequencing interaction effect was predicted. Scrambled item sequences were expected to have a more detrimental effect on the learning of low verbal ability students than on the learning of high verbal ability students. It was thought that students of low-verbal ability would not have the conceptual skills required to reorganize the scrambled material.

Methods and procedures

Description of instructional system (CAI) and course materials. The course used in the first experiment was a section of a modern mathematics course which has been developed for CAI by the staff of the Computer Assisted Instruction Laboratory of The Pennsylvania State University.[1] The material

[1] The writer would like to thank Professor Alan Riedesel and Marilyn Suydam of the Penn State Computer Assisted Instruction Laboratory who developed the Modern Mathematics program.

selected contains instruction on the use of number systems with bases other than ten This learning task offers the advantage of being relatively difficult for college students to learn, and the material is unfamiliar to most students. The ordered version of the program presents subsets of items in the following sequence. review of the base ten system; the concept of place value; the application of the concept of place value in base eight, base two, and base twelve number systems; transformations from one base to another; addition and subtraction in numbers systems with bases other than ten; and multiplication and division in number systems with bases other than ten Previous experience with these course materials indicated that most undergraduate college students could complete instruction in approximately two and one-half to three hours with a mean error rate of about fifteen per cent

The course materials used in the present study were prepared for CAI by means of a special computer language known as Coursewriter developed by I.B M. computer scientists at the Thomas J Watson Research Center, Yorktown Heights, New York Using the Coursewriter language, a course was programed including questions, problems, correct answers, incorrect answers, knowledge of results, and remedial branches, all of which were stored on magnetic discs to which the computer has selective access to any part with an access time of less than one second The computer was programed to accumulate and store all student errors and response latencies, and these data were later retrieved for the investigators by means of a special program called Student Records The scrambled sequence version of the number systems program was established by rearranging the sequence of frames according to a table of random numbers The scrambled sequence was then entered and stored on the magnetic discs as a separate course

The central computer used in the study was an I B M. 7010-1410 system located at I B M s Thomas J Watson Research Center, Yorktown Heights, New York

The course materials in the form of questions, problems, prompts, etc , were teleprocessed over long distance telephone lines to student terminals on The Pennsylvania State University campus The course was presented to students via an I B M 1050 student terminal which consisted of a modified electric typewriter, and a random access slide projector and tape recorder (the slide projector and tape recorder were not used in the present study) Questions and problems were typed out to the student, who typed his responses at the terminal The student relayed his responses to the central computer which evaluated the response, provided knowledge of results, and sequenced the student to the next appropriate step in the course.

<u>Subjects and procedures</u>. Fifty-one undergraduate students in an introductory educational psychology class at The Pennsylvania State University served as the Ss in the investigation <u>S</u>s with absolutely no previous typing experience were not included in the study. Two <u>S</u>s were eliminated because a modern mathematics pretest indicated they had previous knowledge of number systems with bases other than ten One other <u>S</u> was eliminated because his scholastic aptitude test scores (SAT) were not available These eliminations brought the total number of <u>S</u>s to 48.

Subjects were then subdivided into high- and low-aptitude groups on the basis of their scores on the verbal Scholastic Aptitude Test (SAT) The mean of the high group was 612 and the mean of the low group was 435 (SAT employs standard scores based on a mean of 500 and a standard deviation of 100) The original plan of the investigation was to assign <u>S</u>s within each of the high and low aptitude groups at random to the scrambled or ordered instructional treatment conditions Although approximately half of the <u>S</u>s were assigned to treatments at random, the random assignment of a large number of <u>S</u>s had to be altered due to a number of programing "bugs" which developed at the last minute in the scrambled sequence program For this reason, a larger number of Ss who were scheduled for the early experimental sessions were run in the ordered sequence condition, and a larger number of Ss scheduled for the later experimental sessions were run in the scrambled sequence condition. The investigator had carefully examined the two groups of subjects and in spite of the non-random assignment of some of the Ss, can find no selective factors which could account for the results obtained in the study However, to provide additional assurance of the reliability of the results, a second independent replication of the study is presently in progress

The Ss reported to the Computer Assisted Instruction Laboratory individually and were given Form A of a 23-item achievement test as a pre-treatment examination to test the prior knowledge of number systems with bases other than ten in t·a''y. S was given a warm-up to familiarize him with the student typewriter terminal After a warm-up period of about fifteen to thirty minutes, S was allowed to begin instruction on the number systems program At the completion of the program, S was given Form B of the 23-item achievement test on number systems The reliability of Form B of the criterion measure estimated by the Hoyt technique was found to be .93 in an earlier study (Mitzel and Wodtke, 1965) The test-retest reliability of the criterion measure was also found to be .93 for a one-week interval between testings in the earlier investigation Following the achievement posttest, all Ss completed a Student Reaction Inventory consisting of Semantic Differential type items (Osgood et al., 1957) designed to measure the student's attitude towards CAI.

All Ss were allowed to complete the instructional materials at their own rate Thirty-seven Ss were able to complete the program in one evening, while 11 had to return the following day to finish the material Two Ss in the scrambled sequence group were scheduled to return the following day to complete instruction, but they never returned These two Ss seemed highly frustrated by the scrambled sequence program

As previously mentioned, two Ss were eliminated because their pretest scores indicated prior knowledge of number systems. The remaining Ss who were included in the study achieved, on the average, one-half point on the pretest Seventy per cent of the Ss obtained a score of zero on the pretest indicating that the students had little or no prior knowledge of number systems with bases other than ten

The dependent variables of the study were criterion test performance, errors made in the program, total time taken to complete the program, mean response latency per frame, an efficiency score obtained by taking the ratio of criterion test performance to instructional time, and measures of the students' attitudes towards CAI. The data were analyzed by means of a two by two factorial analysis of variance design with unequal numbers of cases per subcell One experimental factor consisted of high versus low aptitude; the other of scrambled versus ordered program sequence

Results

A preliminary analysis indicated that although the high- and low-aptitude groups differed significantly on the verbal SAT measure, the scrambled and ordered sequence groups did not differ significantly in verbal ability as measured by the SAT In addition, an analysis of Quantitative SAT scores produced nonsignificant differences among the four treatment groups employed in the study.

The distributions and, within groups, the variances of the dependent variables were examined to determine whether the assumptions underlying the analysis of variance had been met None of the distributions appeared to deviate substantially from normality Hartley's Maximum F-ratios were computed to test the assumption of homogeneity of variance All of the F-ratios were nonsignificant except one The F-ratio for the efficiency score was significant at less than the .01 level indicating the presence of heterogeneity of variance for this variable In view of the results obtained by Boneau (1960) and Norton (1952) who found that heterogeneity of variance did not seriously bias either the t-test or F-ratio, the heterogeneity of variance for the efficiency score could not have seriously biased the results obtained in the present study.

In general, the results of the analysis of the main dependent variables of the study confirmed the initial expectations Table 1 summarizes the results of the analyses of variance of three of the dependent variables, frequency of errors made in the program, per cent errors, and criterion test score The results indicated that students in the scrambled sequence group made significantly more errors during instruction than the students in the ordered sequence group ($P < .001$) Since the students in the scrambled sequence group were more likely to encounter remedial segments of the program (due to their greater tendency to make errors), than the students in the ordered group, the scrambled sequence group actually responded to more questions than the ordered sequence group The differences obtained in the total frequency of errors might have resulted from the fact that the students in the scrambled group simply responded to more questions and thus had more opportunity to make errors than the ordered group To control for this possibility, an analysis was also computed based on per cent error scores As shown in Table 1, this analysis also indicated that students in the scrambled sequence group made a significantly greater percentage of errors than the ordered sequence group. In spite of the highly significant sequencing main effect for frequency and percentage of errors, the sequencing main effect for the criterion test score was nonsignificant. Considered together, these results indicated that although the scrambled

Table 1

Analyses of Variance of Frequency of Errors, Per Cent Errors, and Criterion Scores for High- and Low-Aptitude Students in Scrambled and Ordered Sequence Conditions

Source	d.f.	Frequency of Errors F-ratios	Per Cent Errors F-ratios	Criterion Score F-ratios
Aptitude	1	1.48	2.42	.27
Sequencing	1	12.65***	11.94**	1.40
Aptitude x Sequencing	1	3.96*	.69	3.62*
Error	44	(529.26)[a]	(801.60)[a]	(32.07)[a]

[a] Equals the mean square of the error term
* P is less than .10
** P is less than .01
*** P is less than .001

sequence students made significantly more errors during instruction than the ordered sequence Ss, they apparently improved their performance during instruction and, by the end of the course, they performed approximately at the same level as the ordered group on the criterion measure. A more detailed analysis of the frequency of correct responses during instruction is being undertaken to determine whether students in the scrambled sequence group showed improvement from the beginning to the end of the course.

The results reported in Table 1 also show that the predicted aptitude by sequencing interactions were obtained. The interactions for frequency of errors and the criterion measure were both very close to significance at the evel. However, the interactions which were obtained for several criterion var. did not result from a decrement in the performance of the low-aptitude group in the scrambled program as predicted, but from a decrement in the performance of the high aptitude Ss in the scrambled program The results of the present study support the conclusion that scrambling an instructional program has little or no effect on the performance of low-aptitude students, but produces a rather marked decrement in the performance of high-aptitude students The graphs of the interactions for the frequency of errors and criterion test variables are shown in Figs 1 and 2 Both of these figures show the sharp drop in performance of the high-aptitude students in the scrambled sequence program

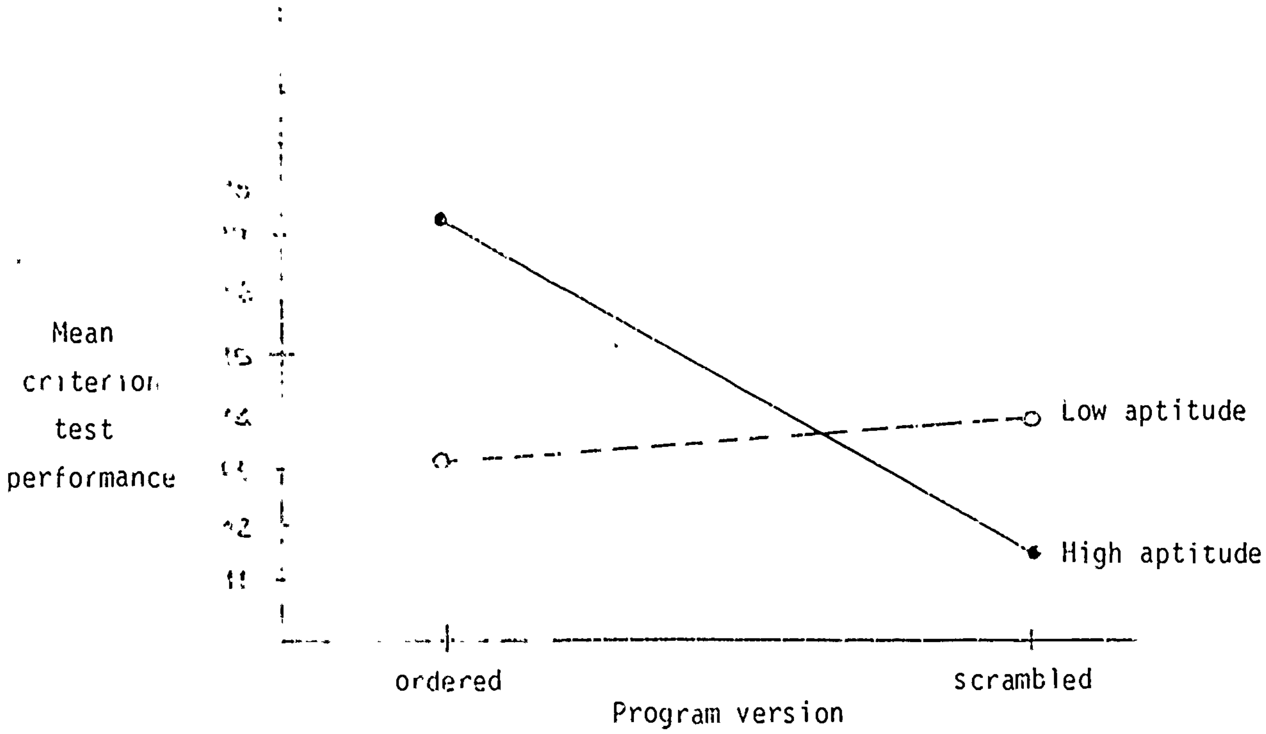

Fig 1 Criterion test performance of high-and low-aptitude groups taught by scrambled and ordered instructional programs (N s equaled: HA-ordered = 17, HA-scrambled = 9, LA-ordered = 14, LA-scrambled = 8)

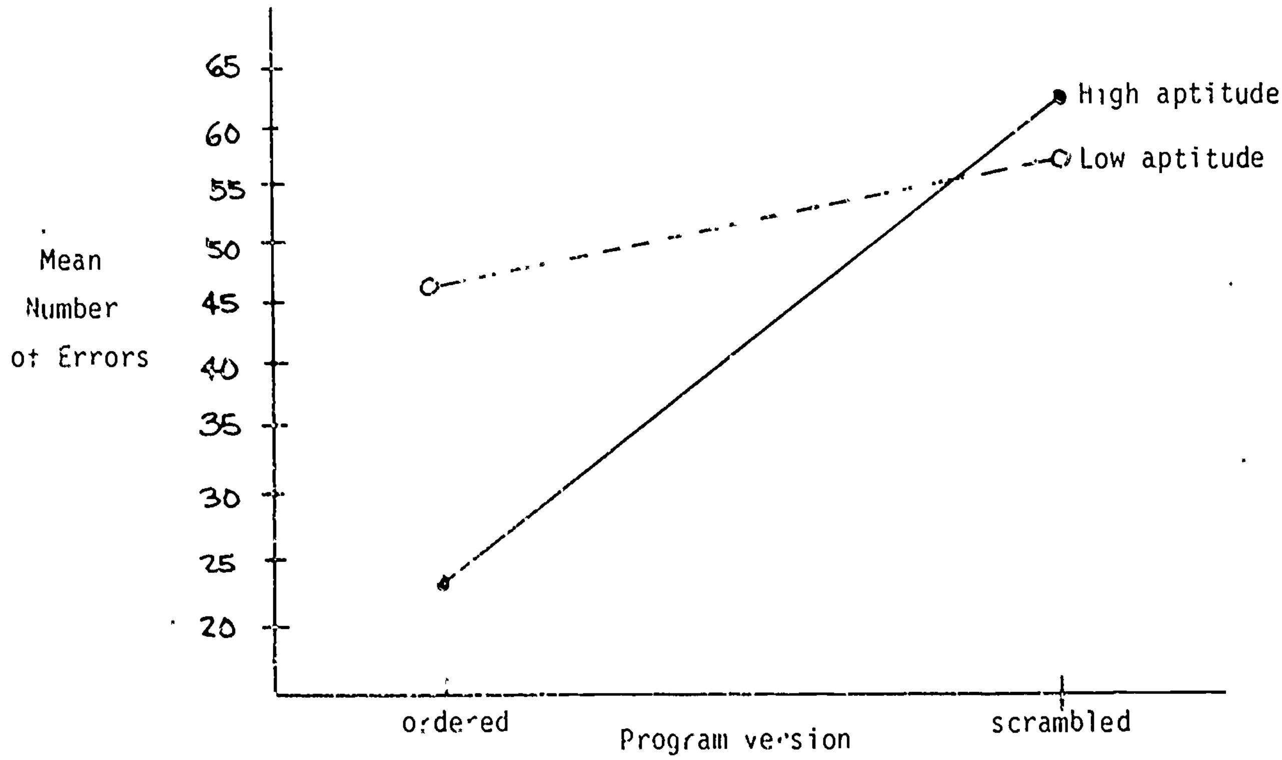

Fig 2 Mean number of errors of high- and low-aptitude students taught by scrambled and ordered programs. (N's equated: HA-ordered - 17, HA-scrambled = 9, LA-ordered = 13, LA-scrambled = 9)

The analyses of other dependent variables are consistent with the results already reported Table 2 shows the analyses of variance summaries for total instructional time, average response latency per frame, and the efficiency score measures Students in the scrambled sequence group took significantly more time to complete the program than students in the ordered sequence group ($P < .001$) The scrambled sequence group took on the average 45 minutes longer to complete the program than the ordered sequence group The longer total instructional time taken by the scrambled sequence group was not simply the result of their responding to more questions than the ordered group The results reported in Table 2 also indicate that the scrambled sequence group on the average took longer to respond to individual frames of the program The sequencing main effect for the average response latency variable was significant at less than the 01 level The scrambled sequence students took on the average 2 05 minutes per frame to respond, while the students in the ordered sequence group averaged 1 59 minutes per response.

The efficiency score reflects the amount learned per unit of time as measured by the criterion measure of achievement The efficiency score was obtained by taking the ratio of a student s criterion test performance to his total instructional time The results reported in Table 2 show a sequencing main effect which was statistically significant at less than the 01 level

Table 2

Analyses of Variance of Total Instructional Time, Average Response Latency, and Efficiency Scores for High- and Low-Aptitude Students in Scrambled and Ordered Sequence Conditions

Source	d.f	Total Time F-ratios	Ave. Resp. Latency F-ratios	Efficiency Score F-ratios
Aptitude	1	79	1.63	2 07
Sequencing	1	14 33***	10.77**	7.50**
Aptitude x Sequencing	1	2 52	.02	4 75*
Error	44	(1591.03)[a]	(.22)[a]	(3475 43)[a]

[a] Equals the mean square of the error term
* P is less than 05
** P is less than 01
*** P less than .001

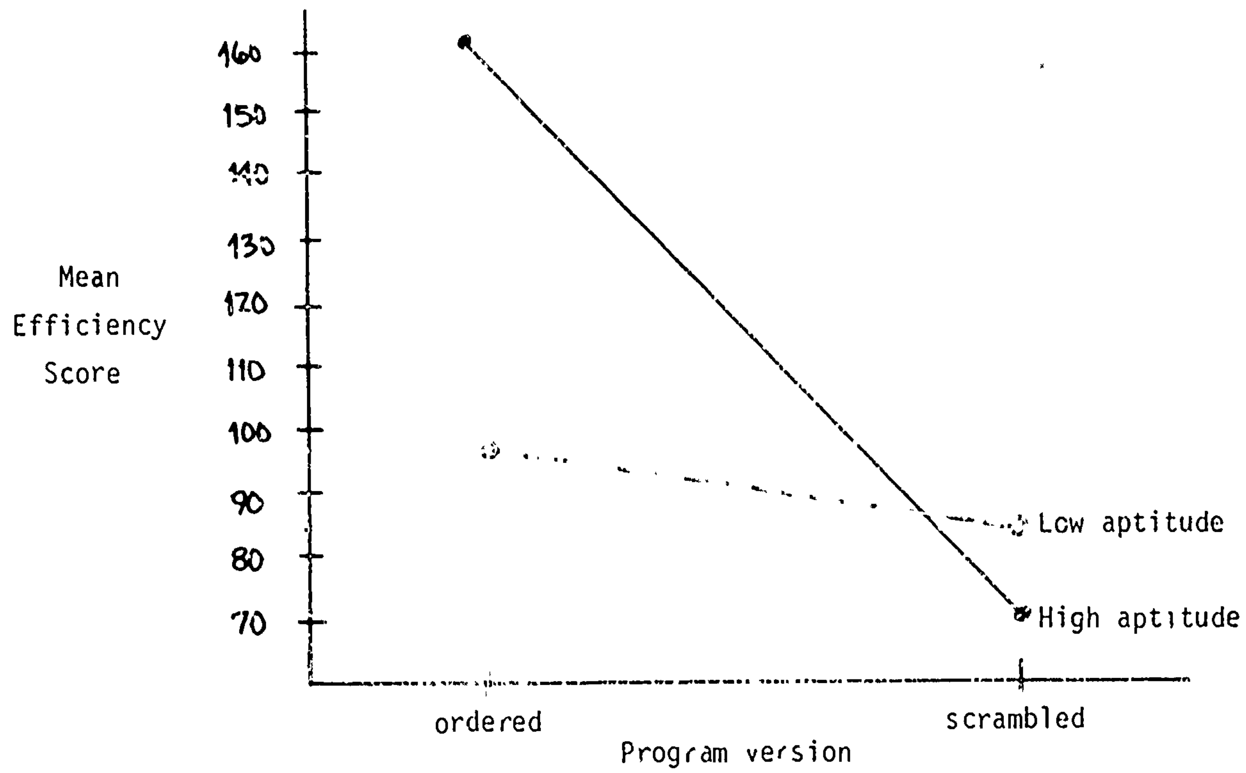

Fig. 3 Mean efficiency scores of high- and low-aptitude students taught by scrambled and ordered programs (N's equaled: HA-ordered = 17, HA-scrambled = 9, LA-ordered = 13, LA-scrambled = 8)

If one compares only the criterion test performance of the scrambled and ordered sequencing groups, as was reported in Table 1, it is interesting to note that the difference is nonsignificant The most likely explanation for this finding is that the additional instructional time and remedial frames taken by the students in the scrambled sequence group brought their performance up to a level comparable to that of the ordered sequence group When the additional instructional time taken by the scrambled sequence group is taken into account by using an efficiency score, the scrambled sequence program is found to be far less efficient that the ordered program

A statistically significant aptitude by sequencing interaction was again obtained in the analysis of the efficiency scores (P .05) This result is consistent with the interactions reported for the error and criterion variables. The scrambled instructional program produced the largest decrement in the efficiency of performance of the high-aptitude students This interaction is shown graphically in Fig 3, which shows the relatively sharp drop in the efficiency scores of the high-aptitude group in the scrambled sequence condition

In considering the three interactions depicted in Figs 1 through 3, the reader should keep in mind that, in each case, the high-aptitude students in the scrambled sequence condition took the <u>most</u> instructional time but showed the <u>poorest</u> performance of all the treatment groups

We may summarize the results reported to this point as follows:

1) When considering the overall main effects for scrambled as compared to ordered sequencing conditions, the results indicate that scrambled presentation of course materials produces more errors in the program, increases total instructional time, increases response time per individual question, and decreases the efficiency of instruction as indicated by the amount learned per unit of time If one examines only the overall effects of sequencing on criterion performance without taking into account the differences in instructional time, and differences in student aptitude, nonsignificant differences are obtained Results for the sequencing main effects indicate that students make more errors during instruction in the scrambled sequence condition, but that they may be able to compensate for the greater difficulty of the material [illegible]ing more time, by studying remedial frames, and by piecing relevant info[illegible]on together as it is made available in the scrambled instructional sequence Thus, by the end of instruction, the performance of students in

What would account for the large decrements in the performance of the high-aptitude students in the scrambled sequence condition? Why did the low-aptitude students show relatively little drop in performance in the scrambled sequence condition? One possible explanation for the results obtained is that one cannot impair performance by scrambling a program if performance is already quite poor The large decrement in the performance of the high-aptitude students resulted in each case from the fact that their performance was quite high in the ordered condition and then dropped to the middle range in the scrambled sequence condition The high-aptitude students had farther to drop The low-aptitude students, on the other hand, started out in the middle range of the scale in the ordered sequence condition This explanation might be plausible if there was evidence that the students were approaching the "floor" of the criterion test However, the frequency distributions of performance on the criterion measure did not indicate that positively skewed distributions occurred which are typical when floor effects are encountered. If anything, the distributions tended to be slightly negatively skewed Furthermore, the criterion measure was not a multiple-choice test; thus, a chance score on the test is virtually impossible As already indicated, most students achieved pretest scores of zero In view of these characteristics of the measuring instrument, a mean score of 13 on the criterion test indicates that substantial learning took place during instruction in the low-aptitude-ordered sequence group. In the writer's judgment, the failure of a performance decrement to occur in the low aptitude, scrambled sequence condition was not the result of floor limits in the measuring instrument or of the failure of low-aptitude students to learn in the ordered sequence condition

The probable explanation of the finding that item scrambling produced larger decrements in the performance of the high-aptitude students than in the

Table 3

Analyses of Variance of the Student Reaction Variables Tense-Relaxed, Shallow-Deep, Inflexible-Flexible for the High- and Low-Aptitude Students in the Scrambled and Ordered Sequence Conditions

		F-ratios		
Source	d f	Tense-Relaxed	Shallow-Deep	Inflexible-Flexible
Aptitude	1	39	1 65	04
Sequencing	1	2 26	42	5 38**
Aptitude x Sequencing	1	3 92*	4 58**	002
Error	43	(2 93)[a]	(1 31)[a]	(3 04)[a]

[a] Equals the mean square of the error term
* P is less than 10
** P is less than .05

low-aptitude students was suggested by the results of the analysis of the student reaction data The analyses of variance of the scales of the Student Reaction Inventory revealed significant effects for the three scales shown in Table 3 The significant interaction effect for the Tense-Relaxed self-report rating scale was of special interest The high-aptitude students in the scrambled sequence condition reported being more tense during instruction than each of the other three experimental groups In addition, the high-aptitude students in the scrambled sequence condition reported the instruction to be "deeper" than the other three groups This latter scale probably reflects the students' subjective perception of the difficulty of the program Finally, the students in the scrambled sequence condition tended to rate the program as more inflexible than the students in the ordered condition The students' self-reports on the Tense-Relaxed and Shallow-Deep scales suggest that the scrambled sequence program aroused the anxiety of the high-aptitude students.

It is possible that the increased anxiety of the high-aptitude students in the scrambled sequence condition produced the decrement in their performance

Consider the "instruction" to which the high-aptitude students were subjected in the scrambled sequence condition They were directed to answer questions and solve problems for which they had little or no prior training The solutions and correct answers to many questions depended on prerequisite information which was frequently not available because the carefully sequenced problems were presented to them in random order They made many errors on questions and problems which, in a normal instructional situation, they would expect to answer correctly Couple all this with the fact that such highly able students usually expect to do well on educational tasks, and probably have a high need to excel, and you have a perfect anxiety-arousal situation It is not surprising to find that the high-aptitude students reported being more tense in such a situation, and one would expect such anxiety to interfere with their learning In fact, it is hard to imagine an instructional situation better designed to prevent learning than the scrambled sequence program employed in the present investigation coupled with high student anxiety

The findings of the present investigation have some rather important implications for education and the design of instruction. It is sometimes assumed that the students who suffer the most from ineffective teaching or instruction are the less academically talented We sometimes assume that the high ability of the gifted student compensates for ineffective instruction such as a poorly written textbook, a garbled lecture, or a poorly prepared instructional program. The findings of the present study not only do not confirm this assumption, but indicate that it is the most academically talented student who suffers most from a highly disorganized, scrambled sequence of instruction This finding is of great interest to the writer, who is planning a second study to replicate and extend the findings of this first experiment

Relationships Among Attitude, Achievement, and Aptitude Measures and Performance in Computer-Assisted Instruction

Kenneth H Wodtke

Several recent studies have obtained nonsignificant relationships between measures of general academic intelligence and student performance in an individualized autoinstructional program (Stolurow, 1964; Eigen and Feldhusen, 1964) These results contrast with the results of many previous academic prediction studies which have found statistically significant correlations between academic ability measures and achievement in traditional instruction. The lack of significant relationships between intelligence and achievement in programed instruction has led to a re-examination of the role of intelligence and past achievement in complex educational tasks. The implication of this result is that a well-constructed instructional program minimizes the importance of general intelligence as a determiner of achievement Presumably all students can be brought to the same high criterion performance following instruction, although some may take longer to reach criterion than others Students may reach higher levels of achievement and tend to be more homogeneous in achievement in programed instruction than in traditional classroom instruction. The greater homogeneity of achievement following instruction tends to reduce correlations with general academic intelligence. The findings of Stolurow, and Eigen and Feldhusen are of great potential significance to education and should be replicated with different instructional materials. If future studies demonstrate that individualized programed instruction can minimize the importance of individual differences in student ability, this finding would constitute an educational breakthrough.

Recent efforts in computer-assisted instruction (CAI)(Stolurow and Davis, 1963; Wodtke et al., 1965) have attempted to develop even more highly individualized programs than those used in previous studies CAI courses frequently employ elaborate branching strategies designed to adapt instruction to the abilities, past achievements, and/or interests of the learner. For such adaptive programs, one might also expect correlations between course achievement and intelligence to be low One objective of the present investigation was to examine relationships among academic aptitude, past achievement, and performance in CAI to determine whether the results of previous investigations can be generalized.

As mentioned above, CAI can potentially provide for sophisticated branching strategies based on various student characteristics, such as aptitudes, past achievements, interests, and performance on previous sections of a course. However, before a given variable can be included in the decision logic of a course, the validity of the variable for predicting important aspects of student performance must be established. Once certain predictors of performance in CAI are established, it will be possible to conduct research to determine what kinds of instruction should be provided for students who have different profiles of scores on the past history measures. The second objective of the present study was to determine what student characteristics are most predictive of performance in CAI.

<u>Methods and Procedures</u>

Forty-five college students completed a section of a course in modern mathematics which was presented by means of computer-teleprocessing. The student terminal consisted of an IBM 1050 communications system consisting primarily of an electric typewriter as an input-output device. The frames of the program were typed out to the students at the typewriter, and the students entered their responses by typing them at the terminal Responses were evaluated by the computer which kept track of the students' performance by accumulating their errors and response latencies in counters. These error and response latency data were later retrieved by means of a Student Records program developed by IBM computer scientists Although the student terminals used in the study were located on the campus of The Pennsylvania State University, the computer was located 200 miles away at IBM's Thomas J Watson Research Center in Yorktown Heights, New York. The computer system used was an IBM 7010-1448 system Long distance telephone tie-lines connected the student terminals to the computer, and information was transmitted by means of computer teleprocessing. The course was programed for the computer by means of a special computer language called Coursewriter which was developed by IBM researchers The Coursewriter language has already been described earlier in this report

Each student was scheduled for a three-hour instructional session Upon arriving at the CAI laboratory, each student was pre-examined on his knowledge of the content of the modern mathematics program. The student was then given a warm-up period to familiarize himself with the operation of the student terminal Following the warm-up period, each student completed a section of the modern mathematics course on number systems with bases other than ten Most students completed the course in about 2 to 2 1/2 hours The course contained instruction in base eight, base five, and base two number systems, and transformations from one base to another. The modern mathematics course has been found to be fairly difficult for the average college student, and only a few students exhibit prior knowledge of the concepts as indicated by their performance on the pre-test Following the completion of the course, students were given a criterion measure of their achievement in the course, and responded to a number of [illegible]de scales modeled after the Semantic Differential scales (Osgood et al , 19[illegible] The criterion achievement test was found to have a test-retest reliability (one-week interval) of .93 in an earlier study (Mitzel and Wodtke, 1[illegible]5) The attitude scales were designed to measure the students' reactions to the course, and to CAI in general In addition to the above measures, Scholastic Aptitude Test scores (SAT) and cumulative grade point averages were obtained from the students' records. Additional measures of student performance in the course included errors made in the program, total instructional time, average response time per frame, and an efficiency score which was obtained by taking the ratio of a student's performance on the criterion measure to his instructional time. The various measures obtained in the study were analyzed by means of a Pearson Product-moment correlation computer program. Table 1 summarizes and defines the measures obtained in the study.

Table 1

List of Variables in the Correlational Analysis

Variable No.	Variable Name		
1	Sex		
2	Pretest - Achievement in Number Systems		
3	Posttest 1 - Achievement in Number Systems		
4	Posttest 2 - Achievement in Number Systems		
5	Scholastic Aptitude Test - Verbal		
6	Scholastic Aptitude Test - Mathematical		
	Student Reactions to CAI:		
7	Slow	-	Fast
8	Dull	-	Interesting
9	Tense	-	Relaxed
10	Bad	-	Good
11	Unfair	-	Fair
12	Shallow	-	Deep
13	Worthless	-	Valuable
14	Passive	-	Active
15	Difficult	-	Easy
16	Inflexible	-	Flexible
17	Fast -	Equipment -	Slow
18	Much More Attention to CAI than Classroom Lecture		
19	Adequate Branching - Inadequate Branching		
	Errors Made during Instruction		
	Total Time to Complete the Course		
	Average Response Time (Minutes)		
23	Efficiency		
24	GPA		

Results

The intercorrelations among the aptitude, CGPA, and CAI performance measures are shown in Table 2. A number of questions can be asked of the results shown in Table 2. First, what are the relative contributions of aptitude and college grade point average to the prediction of achievement in the programed course? The results indicate that mathematical aptitude (SAT-M) was a better predictor of criterion test performance following instruction (.50) than either verbal aptitude (SAT-V) (.38) or CGPA (.13). The superiority of the mathematical aptitude predictor is understandable in view of the mathematical content of the CAI course used in the study. A number of partial correlations were also computed indicating that SAT-M uniquely accounted for the most variance in the criterion achievement measure when previous achievement was held constant.

College grade point average did not correlate significantly with achievement in the CAI program. It is interesting to note, however, that although grade point average did not correlate with the amount learned in the program as measured by the posttest achievement measure, it did correlate significantly (.40) with pretest performance. These results suggest that CGPA related to prior achievement level, but not to the amount learned in the course.

The present results are not consistent with the earlier results obtained by Stolurow (1964) and Eigen and Feldhusen (1964). These investigators found that general intelligence was a poor predictor of performance in programed instruction. Eigen and Feldhusen (1964) obtained their highest correlations between measures of past achievement and achievement in the instructional program. In contrast to these results, the present study found mathematical aptitude as measured by the Scholastic Aptitude Test to be a better predictor of CAI performance in a mathematics program than previous general academic achievement as measured by the cumulative grade point average

There are several possible explanations for the differences in the findings. First, it is possible that the modern mathematics program used in the present study did not facilitate student learning as well as it might after further revision. This course has been undergoing constant revision, and it is possible that future versions of the course will produce generally higher levels of achievement in all students, and thereby reduce the correlation with academic aptitude. Examination of the mean criterion performance of high- and low-aptitude groups on the modern mathematics program indicates that the course achieves its objectives quite well with high-aptitude students, but produces only moderate levels of achievement in the low-aptitude students. However, it is difficult to determine whether the differences obtained reflect the inadequacy of the instructional materials or individual differences among the students in aptitudes for the task. The present course version contained extensive remedial material; however, this material did not appear to be very effective with the low-aptitude students. Much more extensive diagnosis and small-step remedial frames may be necessary in order to improve the achievement of the low-aptitude students.

The importance of student aptitude in determining achievement in programed instruction may depend on the content of instruction. Some subject matters may be relatively independent of previous skills and abilities, and achievement of such material would be within the capabilities of most learners. On the other hand, other subjects may be highly dependent on previously learned skills and ap[illegible] These aptitudes may develop as a result of many years of previous learning experiences It would be unreasonable to expect individualized instruction to reduce individual differences in achievement in subject matters in which previously learned aptitudes played an important part. To improve achievement in such a course, the program would have to be designed to help the student develop the prerequisite aptitudes for the task. In some subjects, such as mathematics, it might take a separate course or several courses to develop the necessary aptitudes in the learner. For example, if abstract reasoning ability was essential for the mastery of a task, an instructional program would have to provide special remedial instruction in abstract reasoning for students low in this ability. Without such special training in the program, an investigator could not expect to reduce the covariance between course achievement and measures of the relevant abilities.

The above argument raises some important questions concerning the development of instructional programs, particularly for student populations such as those found in vocational education. What special aptitudes are essential for the mastery of different subjects? If one finds certain student populations lacking in these aptitudes, can the aptitudes be taught by means of remedial instruction? Can the media of instruction be modified so that the same concepts can be taught by instructional stimuli which avoid the learner's weaknesses and capitalize on his strengths? For example, students in vocational training programs are typically somewhat lower in verbal communication skills than general academic students of the same age. These same students frequently exhibit high mechanical, spatial, figural, and creative aptitudes. Such students might show relatively poor achievement in a CAI program which relied solely on verbal or written communication. These students might be handicapped because of their weakness in the verbal communication mode. On the other hand, a program which relied heavily on the presentation of the concepts by means of non... visual stimuli presented on slides might be more effective with students of low verbal ability. The ideal CAI course could be programed to adjust instruction to an entire profile of student aptitudes, thus, the program could select more practice trials for students with low retention scores, and so on. Matching instruction to the profile of learner aptitudes is a challenging educational problem. We plan to concentrate a considerable amount of our future research in this area.

The results shown in Table 2 also indicate that errors made during the instructional program were a highly significant predictor of performance on the criterion achievement test (- 83) This finding tends to support the practice of using cumulative errors as one of the bases for branching in instructional programs. However, in some instructional programs it is desirable to select appropriate instruction for a student <u>before</u> his errors occur. Thus, it would be desirable to have a good predictor of student errors so that students could be branched to more appropriate material prior to the occurrence of the incorrect response. Some measures which may prove to be valuable predictors of student errors are aptitude, past achievement, and response latency variables. These measures may provide the earliest possible signs that a student will experience difficulty in learning certain subject matters

The measures of aptitude, college grade point average, and response latency were analyzed by means of partial correlations to determine which variables contributed to the prediction of student errors made during instruction. However, the results of multiple regression analysis now in progress were not available in time to be included in the present report. An examination of the zero-order correlations shown in Table 2, and the partial correlations indicated that both the aptitude and grade point average variables added to the prediction of student errors. The partial correlation between mathematical aptitude and errors with grade point average held constant was -.53. The partial correlation between grade point average and errors with mathematical

Table 2

Relationships Among Aptitude, Achievement, and Performance in CAI[a]

	Posttests	Errors	Total Time	Avg Resp Time	Efficiency Score	SAT V	SAT M	GPA
Pretests	25*	- 22	-.33**	- 37**	53***	26	16	40**
Posttest		- 83***	-.51***	- 30**	81	.38**	.50***	.13
Errors			.74***	.46***	-.79***	-.47**	- 49***	- 36**
Total Time				90***	-.80***	-.30*	- 42**	-.32*
Avg. Resp. Time					-.67***	-.13	-.36**	- 25
Efficiency Score						45**	.46**	29
SAT-V							46***	43**
SAT-M								.03

*p < .10

**p < .05

***p < .01

[a]Since all measures were not available for all subjects, a missing-data correlation program was used. The sample sizes in this table varied from 29 to 44.

itude held constant was - 40 Mathematical aptitude and GPA made independent contributions to the prediction of student errors, because they both correlated significantly with errors, but did not correlate with each other.

CAI researchers have shown considerable interest in the use of response latency measures for diagnosing and predicting student errors Most CAI systems can record the latency of student responses for individual frames, problems, or questions in a course. If an increased response latency signifies the increased probability of an error, the computer could be programed to provide some remedial instruction or prompts when response time exceeded a specified limit In this way, the program could anticipate errors before they occurred and take appropriate steps to assist the student. In the present study, the zero-order correlation between mean response latency for all frames in the course and total number of errors was 46 A partial correlation was computed between mean latency and number of errors holding constant both the SAT-M and GPA measures The partial correlation was 27 which approached statistical significance The reader should note that the present analysis considered only mean latency determined over all frames correlated with the total number of errors In view of the many factors which may determine the total number of errors made by a student in a course, the relatively low partial correlation of 27 between mean response latency and total errors is not surprising The response latency measure may be more predictive of the occurrence of an incorrect response for individual frames in the program. An [illegible] of individual frames in the modern mathematics program is being made [illegible]mine whether incorrect responses are more probable following long respo[illegible]cies If the results of the detailed analysis are consistent with the results reported above for the global analysis of errors, future [illegible] programs could profitably employ branching strategies based on the student's response latencies

Table 3 shows the correlations of the attitude scales with SAT scores and the measures of performance in CAI. In addition, Table 3 contains point-biserial correlations between the sex of the student and the attitude measures. Several correlations approaching statistical significance suggest the presence of sex differences in student reactions to CAI. Males tended to find CAI more interesting (.27), more relaxed (.24), more valuable (.25), and more active (.21) than females. Similar sex differences in reactions to CAI were obtained for a previous sample of 47 students who completed several different CAI courses. Although the women tended to react to CAI slightly more negatively than men, the correlations between the sex of the student and performance in the course were all essentially zero. Whatever the reason for the more negative attitudes of the women, their attitudes did not appear to influence their performance in the course. The different reactions of men and women to CAI probably resulted from differences in their interest patterns. Women are typically more prone to dislike complex machinery than men; furthermore, the mathematical content of the course used in the present investigation represents a subject matter area in which men generally manifest stronger interests. We are looking forward to replicating this finding with some course materials which are less biased in interest value for men and women. This replication will provide information as to whether women react negatively to CAI in general, or just to particular courses and content areas.

A number of statistically significant correlations reported in Table 3 indicated that the high-aptitude students tended to react more favorably to ... than did the low-aptitude students. However, these correlations may simply ...ct the fact that the high-aptitude students did better in the course than the low-aptitude students as indicated by the significant correlations between the aptitude and CAI performance measures It is conceivable that students might react negatively to any instructional method in which they performed poorly Several partial correlations were computed between intelligence and attitude towards CAI, with performance in CAI held constant, to determine whether aptitude related to attitude towards CAI is independent of performance Holding criterion performance constant by means of partial correlation, mathematical aptitude (SAT-M) correlated 35 with the Bad-Good attitude scale, and 35 with the Worthless-Valuable attitude scale These correlations were statistically significant at less than the 05 level Holding errors constant by means of partial correlation, SAT-M correlated 41 with the Bad-Good scale and 39 with the Worthless-Valuable scale These correlations were also significant at less than the 05 level These results suggest that students of higher mathematical aptitude reacted more favorably to CAI instruction in modern mathematics than students of lower aptitude, and that the favorable reactions did not depend entirely on the fact that they performed well in the course These results should be replicated with other course materials to determine whether the relationships obtained simply reflect the strong interest of the high-aptitude students in the mathematical content of the present course, or whether the relationships reflect a generally favorable attitude to CAI

Did the students' expressed attitudes towards CAI affect their performance in the course? Several partial correlations were computed between the attitude measures and CAI performance with aptitude held constant. None of these correlations was statistically significant. Attitude towards CAI did not appear to affect performance when the effects of aptitude were partialed out [illegible]termination of the effects of attitude towards instruction on performance present some serious methodological problems In order to assess student's attitude towards a new and novel method of instruction such as

CAI, it is necessary to administer the attitude measure following instruction. This procedure thus confounds the student's attitude towards the method of instruction with his level of achievement in the course. It would be impossible to determine the direction of causation for a correlation between attitude and performance in CAI, did a negative attitude cause poor performance, or did poor performance cause a negative attitude towards the method? It also makes no sense to administer the attitude measure prior to CAI instruction, since the students have had no previous contact with CAI. Fortunately, this problem caused no difficulty in the interpretation of the present results, since non-significant correlations were obtained between attitude and performance with aptitude held constant; however, had significant correlations been obtained there would have been no way to determine the direction of the effect.

Summary

The results of the present investigation may be summarized as follows:

1) The present results do not agree with the results of several previous investigations which found nonsignificant relationships between achievement in programmed instruction and measures of general intelligence. Significant correlations were obtained between Scholastic Aptitude Test scores and a criterion measure of achievement in modern mathematics presented by computer-assisted instruction. Although it may be reasonable to expect individualized programed instruction to reduce individual differences in student achievement in some content areas, student performance in other content areas may depend on [illegible]uisite skills and abilities which have deep roots in many years of previous tra[illegible]

2) Cumulative college grade point average was found to correlate significantly with modern mathematics achievement level prior to CAI instruction,

but did not correlate significantly with post-instruction achievement level This result suggests that grade point average reflects the amount of prior achievement, but is not a good predictor of how much a student will learn in short periods of instruction via CAI

3) The best predictors of student errors made during CAI were SAT-M, SAT-V, CGPA, and response latency in that order. The results suggest that the latency of a student's response might be used as a signal to the computer to present remedial instruction and thereby prevent the occurrence of an incorrect response.

4) A measure of the students' attitudes towards CAI indicated that college students generally reacted favorably to the experience. However, men tended to react more favorably than women, and high-aptitude students tended to react more favorably than low-aptitude students.

5) Nonsignificant relationships were obtained between attitude towards CAI and performance in the course when the effects of aptitude were partialed out.

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APPENDIX

THE FIRST GENERATION OF COMPUTER-ASSISTED INSTRUCTIONAL SYSTEMS: AN EVALUATIVE REVIEW

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Introduction

After developing machines which could automatically teach drill material and administer and score tests, Pressey (1926, 1927, 1932) argued that the advance of a science is dependent upon the technological improvements made in that science. His contributions to the "educational revolution" were not to be realized, however, until Skinner (1954) cogently argued that mechanical means were necessary to arrange the "contingencies of reinforcement" which would allow a student to learn more rapidly and effectively than he could if he were under the unsystematic--and often aversive--reinforcement schedules of the classroom. This argument was attractive to psychologists and experimental educators because it offered the opportunity to apply the psychological principles of learning, derived from the laboratory, to the classroom.

Historically contiguous with the first tidal wave of teaching machines and programs was a torrential deluge of criticism being directed toward education. A re-examination of the methods and goals of education followed and with it came federal aid to education. Programed[1] instruction emerged in high repute from these educational debates, probably because its advocates claimed the following virtues for it: (1) it was based on scientific principles; (2) it could alleviate the problem of teacher shortage; and (3) it was geared to the individual student, who could learn at his own rate and eventually master the material.

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[1] I shall follow the grammatical rule (Markle, 1961) of spelling programed with one "m" when referring to programed instruction: however, I find it useful to make the distinction (suggested to me by Professor Keith Hall) of spelling it with two "m's" when referring to computer programming. This distinction will be adhered to in this paper, except to preserve the accuracy of quotations.

If a simple machine like Pressey's could teach, it was soon asked, why not use a digital computer, which could really adapt to individual differences by incorporating Crowder's (1960) branching procedures in on-line[2] real-time[3] instructional decision-making?

That this was begun with some alacrity is attested to by Dick's (1965) summary of the computer-based systems in operation. This field has expanded so rapidly, however, that Dick's review already requires up-dating. The purpose of this paper is to examine the research and development trends in computer-assisted instruction (CAI) from the standpoint of the problem of communication.

CAI AS COMMUNICATION

Defining communication as all the procedures by which one mind may affect another--which includes music, art, education, and automatic equipment--there are three communication problems to be solved: the Technical Problem, the Semantic Problem, and the Effectiveness Problem (Weaver, 1963).

Phrased as a question the *Technical Problem* is: how accurately and rapidly can the symbols of communication be transmitted from sender to receiver? For CAI this is a hardware problem dealing with the technology of the computer and input-output devices.

The *Semantic Problem*, asking how precisely the transmitted signals convey the desired meaning, is concerned with the identity or satisfactorily close approximation in the interpretation of meaning by the receiver as compared with the intended meaning of

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[2]On-line refers to equipment whose operation is under the direct control of the computer as opposed to off-line equipment operation, where tasks are performed by conversion of information from cards to tapes to cards, etc.

[3]Real-time operations are those in which an event is controlled by information generated by the event; that is, the event is controlled by feedback processes.

the sender. For CAI this is the problem of writing instructional programs.

The Effectiveness Problem is concerned with how effectively the received meaning affects conduct (changes behavior) in the desired way. This for CAI is the problem of learning and the measurement of that learning.

Despite the fact that these three problems are typically attacked by three different professional groups (the first by engineers, the second by educators and linguists, and the third by psychologists), these are by no means unrelated problems. CAI offers a unique opportunity for these three disciplines to pool their efforts toward the common goal of solving the problems of educational communication. An excellent example of a multidisciplined approach to this problem, with an emphasis on the student-subject matter interface or interaction, is the program beginning at the University of Pittsburgh's Learning Research and Development Center (Glaser, Ramage, and Lipson, 1964).

THE TECHNICAL PROBLEM

The Technical Problem in CAI is primarily concerned with input-output devices and costs. Developments in computer speed, memory access time, and cost per bit of information have shown tremendous advances. Operating speeds, presently discussed in milli- and micro-seconds, are beginning to be discussed in nanoseconds[4] (Borko, 1962). Increased memory storage capacity can be expected for the future with photographic storage systems as well as electronic

[4]One nanosecond equals one billionth of a second.

systems (Borko, 1962). Associational memories, in which the information received is interpreted in terms of previous experiences through associations with past responses, are being explored (Flood, 1963). These, if successful, should prove quite adaptable for teaching. Advances such as these have led Clippinger (1965, p. 207) to remark:

> Today's fastest machine cannot be loaded down and will be idle most of the time unless it is coupled to a large number of high speed channels and peripheral units. . . .The only solutions are: (1) many fast [memory] drums for buffers, or (2) multiprogramming[5] to match the high flow problems to the low flow problems, or (3) idle time.

Families of compatible computers are being manufactured giving greater possibilities for multiprocessing[6] of problems, allowing optimal employment of all parts of the computer. Nevertheless, certain needs are evident: (1) increased speed of input/output systems, (2) greater storage for time-sharing systems, and (3) better display systems (Fernbach, 1965). The first two needs do not yet directly concern CAI since present input-output speeds and storage space are more than adequate for the present instructional uses. Display systems and other input-output devices are, however, a current concern. Some of the devices presently in on-line use or as experimental prototypes for future use are the following:[7]

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[5]Multiprogramming is automatic time sharing of common pieces of the computer system for different problems (Estrin, 1962). Time sharing, as we shall see, is the most frequently suggested method of reducing cost per student and increasing total system efficiency.

[6]Multiprocessing: simultaneous or parallel functional operations.

[7]For a further excellent discussion of these devices see Glaser et al. (1964)

1. Visual Communication:

   a. Typewriters are used as input-output devices under computer control (e.g., to ask the student a question or to direct him to some reading material) or under student control (e.g., to answer the question).

   b. Film Projection Devices:

      (1) The Thompson Ramo Woolridge Mentor selects films on the basis of real-time responses, presents auditory and visual materials, and can score student responses automatically (Chapman and Carpenter, 1962).

      (2) Displays may now be created in real-time by superimposing symbols on a film-projected background to highlight certain aspects of the film. As film development time is shortened (it now takes 10-15 seconds) it will be possible to photograph new information and update a display almost immediately.

   c. Cathode Ray Tubes are the most adaptable visual displays for real-time usage and changing display material. Using a light pen held near a screen, one can draw curves (although the present capacity for handdrawn responses is limited) or indicate answers, which can then be evaluated by the computer by plotting coordinates. These devices are being developed in color, for three dimensional displays and with image storage capabilities. Because of the present need for large coaxial cables connecting the computer and the cathode ray tube, they must remain in close proximity.

d. Random access slides and films are also in popular use.

2. Auditory Communication:

In addition to random access tape recorders which are in general use, prototypes are being developed for speech generation and recognition. Two types of speech generation devices being developed are the following:

a Compiled speech, where the computer has random access memory of prerecorded words or phrases which are then arranged as output on the basis of a student's response (e.g., the computer could tell a student the formula of a chemical).

b. Synthetic speech, where the computer uses a set of rules to convert stored speech sounds into meaningful speech patterns.

Speech recognition is more difficult because the acoustic cues of verbal communication are not completely understood, and the receptor must be capable of adjusting to variations such as speaker intonation, loudness, rapidity, and length of the spoken phrase. Character readers, designed to convert words or numerals into a computer code without human intervention, are also becoming commercially available while prototypes of equipment capable of scanning a page of ordinary type and coding it for the computer have been developed (Borko, 1962).

Besides the response devices already discussed, such as the typewriter and light pen, a manipulation board for children has been developed. It is capable of providing information concerning the shape and orientation of blocks and other items on its surface.

Finally, although the present generation of computers is fairly reliable in terms of repairs, computers must become more reliable for real-time operations where "down time" will be a nuisance in addition to being costly (Borko, 1962).

Computer Programming[8]

While much research needs to be done on most of these technical devices to make them practically feasible, most researchers would agree that programming, not equipment improvement, is the major computer problem. Time-sharing, multiprocessing, mass information retrieval, and storage allocation, to name a few, are systems' concepts of today and tomorrow--and they are programming system concepts (Brooks, 1965).

Increased capabilities of computer systems have led to problems in compiling and debugging large programs and in developing executive

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[8]Although computer programming is really a semantic problem from the standpoint of communicating "meaning" between programmer and machine, it has been included under the technical problem here. The reason is that for most CAI programers the semantic problem deals with instructional programs, and the computer programs which translate these instructional programs into machine language are technological givens.

systems to control time-shared systems. Further progress in developing these systems ". . will depend very much on the work of theoreticians, and several moves have been made in recent years towards establishing a theoretical basis for programming" (Gill, 1965, p. 204). One such attempt is Naur's (1965) conception of programming as a tool which interacts with people and problems in a symmetric manner.

Instructional programming can make use of the computer's calculation powers. More useful, however, may be its learning and decision-making powers, especially in systems designed to adapt to individual differences and "learn" from this "teaching experience." More about these instructional systems later.

THE SEMANTIC PROBLEM

Arbitrarily limiting the semantic problem to meaning conveyed by the instructional program may result in some confusion, despite the qualification in footnote 8. For example, Mrs. Aiko Hormann of System Development Corporation (SDC) is developing a computer system[9] called "Gaku" (a Japanese name for learning) which is capable of learning from a human tutor, who instructs it by presenting samples of problems previously solved, general information in the form of a lecture, and suggestions as to how to solve the problem. CAI is usually involved in having the computer-tutor teach human students. Both approaches involve the conveyance of desired meaning via instructional programs. The main difference perhaps is that in the former case the instructional program involves programming the

[9] _____, 1965, "Gaku: A Computer System that Learns to Solve Problems by Experience," Naval Research Reviews, April, pp. 15-16.

computer with a set of explicit heuristics[10] whereas in the latter case this is not required (presumably because the student already has a set of implicit heuristics which he can use). This distinction, however, may not be applicable in all cases (e.g., with experienced computers) and is not necessarily recommended. For the purposes of this paper, then, no distinction will be made although programs utilizing the computer as a "tutor" will be stressed.

It is a popular, although possibly optimistic, opinion that CAI "is limited only by the imagination of the programmers" (Dick, 1965, p. 52). Assuming that this statement refers to the goal of achieving optimum instructional efficiency, there may be definite limits imposed upon the instructor-authors' imaginations. For example, if many of the display devices discussed in the last section prove feasible--and probably every system now in operation includes at least a typewriter, some other visual display, such as slides or a cathode ray tube, and a tape recorder--there exists a distinct possibility that communication channels could be over-crowded leading to error and confusion on the part of the student (Weaver, 1949). Moreover, the conclusions of Travers (1964, p. 3) suggest other avenues of investigation:

> First, no advantage seems to be achieved by transmitting redundant information simultaneously through both the auditory and the visual modality except where unusually high speeds of transmission are involved. These are speeds far in excess of those ordinarily encountered.

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[10]Heuristics: techniques or strategies by means of which the individual can solve problems. They do not guarantee a solution as algorithmic decision procedures do

> Second, switching from the auditory channel to the visual, or the reverse, occupies time which appears to be wasted insofar as learning is concerned. Third, devices which have been used to draw attention to the information transmitted through one sense modality tend to depress the information received through another. Fourth, in broad terms, the data fit well a model of information processing similar to that of Broadbent, or of Feigenbaum and Simon, which portrays the information processing system in its final level as a single channel of limited capacity which can generally handle only information from one source at a time.

Consideration should also be given to the student-subject matter interface (Glaser et al., 1964) to examine the display and response characteristics by which a student can interact most effectively with a given subject matter. That is, display and response modalities may interact with type of learning required, and determination of the optimum modalities for a given subject matter should be a high priority research topic. Other student-subject matter interactions may be found with age of the student; parameters of the learning process; individual or group instruction; competition or cooperation; and individual differences in aptitude, personality traits, or physical disabilities.

Individual Differences

Perhaps the most interesting advantage claimed for CAI is that instruction can be individualized.[11] Stolurow (Davis and Stolurow, 1964; Stolurow, 1964a, 1964b, 1965a, 1965b) has suggested the name ideomorphic programing for this approach which, in addition to using the student's last response, uses all other available past information as well to make a decision as to the next instructional frame

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[11]Evaluation of this so-called advantage is deferred until the Effectiveness Problem is discussed.

or sequence of frames. As an example of what he means, Stolurow argues that someone high in arithmetic computation but lower in arithmetic reasoning could receive an inductively organized sequence of frames, while someone with the opposite arithmetic profile might be given a deductively organized sequence of frames. Or, if a student were high in aggression he could receive "social reinforcers" which were suitable for that personality trait: he cites a study by Frase which showed that aggressive people like aggressive reinforcement such as the remark from the computer, "That was a stupid mistake." (Stolurow, 1965a)

By no means is Stolurow alone in advocating branching decisions which adapt to individual differences. In a series of studies SDC researchers found three response criteria to be important for branching decisions: (1) the specific answers given by a student to certain diagnostic items, (2) the student's cumulative error record over a series of frames, and (3) the student's own assessment of his level of understanding of the concepts covered (Cogswell and Coulson, 1965; Coulson et al., 1962; and Silberman et al, 1961). Bushnell (1962) has suggested historical and personal measures such as IQ, sex, aptitudes, and reading rate in addition to response data; Mager and Clark (1963) have suggested that branching decisions be applied in determining how much a student already knows in a given subject area, so that he can begin a program at the appropriate point; and Keislar (1959) has considered the problem of step-size. Smallwood (1962) has modeled his system after two important properties of a human tutor - namely, adaptability to the student and systematic improvement with experience--pointing out, as was mentioned earlier, the importance of a computer-teacher which can "learn" In addition, Rigney (1962) makes the distinction between remedial sequencing (where a student is sent into a remedial loop on the basis of performance on test frames) and predicted sequencing (where an attempt is made to predict from the subject's characteristics the best path for him to follow through the program).

As Uttal (1962) indicated, a taxonomy of branching logic is needed to allow comparisons of courses on the basis of their logical similarities rather than on the basis of their content.

Programing Educational Material

Assuming that the foregoing discussion is based on sound experimental evidence, a point to be disputed shortly, the next question to be asked is how to program these lessons. Professional instructional programers agree that only a few good frames can be written in a day, so that preparation of a two-hour lesson may take several months (Silberman and Coulson, 1962). To add to the problem of programing a lesson (with which subject-matter the teacher is familiar) the problem of writing in a form acceptable to a computer (which form may be completely foreign to the teacher) is too much to ask. Hence, the search is on for compilers compatible with natural language (see for example Uhr, 1964), so that programing can eventually be no more difficult than writing a book.[12]

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[12] As Bugelski (1964) pointed out, it is ridiculous to ask classroom teachers to program their courses. Even if programing were as easy as writing a book, it would be out of the question to expect classroom teachers to have the time or capability of writing a good program. How many teachers write books? Program writing will ultimately be left to professional programers and their subject-matter consultants.

Recently Zinn (1965) discussed the programing problem in terms of the level or facility with computer languages needed by the author to write his program At the lowest level of computer language difficulty are languages such as PLATO[13] (Bitzer, Braunfeld, and Lichtenberger, 1962) which require only that the author enter his text and rules for evaluating answers The computer has been programmed to accept the text so that the author does not need to learn a computer language IBM's Coursewriter language (Maher, 1964; Maher and Cook, 1964) is an example of a second level, requiring the author to specify his pattern of instruction in a relatively simple language. At the highest level of sophistication an author writes his own computer program for his instructional strategies. This allows him to use the full capability of the computer but necessitates a high level of competence in computer programming [14]

Once the program has been completed and stored in the computer's memory, it can be tested by submitting it to some students. Students' responses are permanently recorded, and these data can be subjected to statistical treatments for evaluations of difficulty and clarity of the frames and for evaluations of student performance. The program thus serves as its own quality control mechanism as well as being a teaching device

But what happens if the student's answer does not correspond with the given answer stored in the computer memory? In more primitive

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[13]PLATO is an achronym for Programmed Logic for Automatic Teaching Operation located at the Coordinated Science Laboratory of the University of Illinois

[14]Zinn is currently preparing an extensive review of systems and available courses in CAI, in which he expands on language difficulty.

systems the author had to anticipate all correct and incorrect answers and store them in the computer. This is no longer necessary. Misspelled words can be accommodated by partial answer processing, and computers are now evaluating answers for which the word sequence is indeterminate (Smith, 1965).

CURRENT CAI SYSTEMS

The discussion of the Technical and Semantic Problems in CAI has been concerned thus far with a "straw machine," as it were. Actual CAI systems in operation or soon-to-be in operation remain to be discussed before the Effectiveness Problem is examined.

International Business Machine Corporation (IBM)

The feasibility of using a computer as a teaching machine was probably first explored at IBM by Rath et al. (1959) who wrote a program to teach binary arithmetic. Programs have since been developed in German, Stenowriting, Statistics, Audiology, Modern Mathematics, Engineering Economics, Cost Accounting, and others (Maher, 1964; Mitzel and Wodtke, 1965; Uttal, 1962). A unique feature of the IBM system is that the computer is located at Yorktown Heights, New York, while there are student-author terminals spread across the country connected to it by telephone lines. Such computer teleprocessing systems now exist at Science Research Associates in Chicago, at The Pennsylvania State University, The University of Michigan, and at Florida State University, in addition to the terminal at the IBM Yorktown Heights research center. Recently a sixty hour course developed at the IBM Field Engineering Division at Poughkeepsie, New York, has gone "on the air" nationally to train IBM customer engineers.[15]

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[15] ______, 1965, "IBM Goes 'On the Air' with Computer Training," Training in Business and Industry, 2, No. 5, 24-27.

Penn State's CAI Laboratory, to illustrate what equipment is available, currently has two student-terminals equipped with type-writers and random-access slide projectors and tape recorders. Not all of the programs utilize all of the input-output devices, although they can be adapted to do this through the Coursewriter author language (Maher and Cook, 1964). A demonstration course in measurement which uses all equipment has been written by Mitzel.

In the near future a computer will be located at the Penn State campus. This will allow for more available research time to follow up some early findings on student and course variables (Mitzel and Wodtke, 1965: Wodtke et al., 1965). In addition, a development and training program in technical education has been proposed (Mitzel and Brandon, 1965).

Stanford University

At the Institute for Mathematical Studies in the Social Sciences, a group of researchers have developed programs to teach mathematical logic and initial reading to elementary school children (Hanson and Rodgers, 1965; Suppes, 1964b: Suppes and Binford, 1965). Using a fast medium-sized computer, they are currently capable of teaching six students simultaneously in a time-sharing system. Their input-output devices are (1) an optical display unit with two projectors to display randomly accessible microfilmed pages of material, to which the student responds by a light pen; (2) a cathode ray tube; and (3) a random-access audio system.

Research is directed toward the development of models for initial reading (Hanson and Rodgers, 1965), critical thinking (Suppes and

Binford, 1965), and decision strategies for optimal instructional procedures (Groen and Atkinson, 1965). Beginning with the Fall of 1966, sixteen instructional stations will be established in an elementary school in California to teach initial reading to 90 students a day.

<u>University of Illinois: Coordinated Science Laboratory (CSL)</u>

The PLATO system (D. L Bitzer et al., 1962), already in the third revision, has lesson programs available in either "tutorial" or "inquiry" logic, ranging from a second grade level mathematics demonstration lesson with a zoo theme to an electrical engineering lesson on Maxwell's Equations for senior engineering students (Lyman, 1964).

Two students at a time may respond via keysets to stimuli presented by cathode ray tubes, which are connected to a medium-size computer. This capability is presently being expanded, however. To change courses on PLATO requires only a change of slides and a parameter tape to be read by the computer [16]

From the standpoint of the student, there are two other interesting practices: (1) students may be allowed to take home homework (Braunfeld, 1964), and (2) students branched into "Help" sequences may press an "Aha" button to return to the main sequence at any time they feel they have had sufficient remedial work.

Research is being directed (1) toward giving nurses training in clinical syndromes (M. Bitzer, 1963), (2) toward developing a CAI system called PROOF to evaluate students' mathematical and logical proofs (Easley et al., 1964), and (3) toward experimental investigations

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[16] This advantage of low-level computer sophistication needed by course authors is achieved at the expense of versatility of the courses, but it remains to be shown if this is a major disadvantage.

(e.g., Avner's 1964 study on heart rate correlates of insight, in which no consistent relationship was found possibly, in Avner's opinion, because of confounded respiration effects).

System Development Corporation (SDC)

The experimental instructional facilities at SDC consist of three major units: (1) a Bendix G-15 general purpose computer; (2) a random-access slide projector, and (3) a typewriter. The major research goal at SDC appears to be to improve the efficiency of the school by the development of technologically feasible systems (Carter and Silberman, 1965; Coulson, 1965a).

Their CLASS (Computer-Based Laboratory for Automated School Systems) project is an elaborate instructional area, in which up to 20 students can receive concurrent automated instruction. Each student has his own input-output facilities which, through time-sharing, allows him to receive a unique sequence of materials and proceed at his own pace. Or, any number of these students could receive group instruction through television, films, lectures, or textbook, but they could respond individually to any question asked of the group. A special teacher console in each classroom area would allow the teacher to check on each student's progress by having the computer turn on a warning light for any particular student when he was not meeting some criterion of performance. This would allow the teacher to give that student the personal attention he needs (Coulson, 1963).

Bolt, Beranek and Newman, Inc. (BBN)

Using a PDP-1B computer with a typewriter, a numerical keyboard, and a cathode ray tube, BBN experimenters have been recent contributors to two research areas and are embarking on a third. The first has been to use the CAI system to investigate perceptual learning (e.g., the identification of nonverbal sounds) varying some of the conditions of the learning--that is, whether S regulated his own program, whether he used a cathode ray tube or a typewriter, whether overt or covert responses were used, and whether contingent feedback was given. For this relatively simple type of learning it was found that neither a variety of study options, an oscilloscope, overt responding, nor contingent feedback improved performance (Swets, 1962: Swets et al., 1964).

The second area has been to explore the possibilities of a conversational computer program for more complex educational uses. For this an ingenious "Socratic System" was devised (Feurzeig, 1965) and was used to help medical students practice diagnoses on the basis of bits of data presented to them in the form of a case history and medical examination (Feurzeig, 1964: Feurzeig et al., 1964; Swets, 1964: Swets and Feurzeig, 1965).

Recently BBN became involved in a program aimed at determining how CAI might improve mathematics and problem-solving teaching at elementary and secondary schools. At least five Massachusetts communities will be involved in this computer teleprocessing venture.[17]

University of Illinois: Training Research Laboratory (TRL)

Much of the research which has emerged from TRL, which is directed by Stolurow, has already been discussed. The SOCRATES (System for Organizing Content to Review and Teach Educational

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[17] ______, 1965, For Your Information Column, Training in Business and Industry, 2, No. 5, p. 10.

Subjects) System has been designed to be an adaptable ideomorphic instructional mechanism. Research at TRL is generally concerned with isolating the effects of the important variables of learning in CAI (Stolurow, 1965b).

University of Pittsburgh: Learning Research and Development Center

The CAI laboratory here includes four laboratory areas equipped for remote computer control for group and individual learning experiments. Plans are to accommodate six students simultaneously.

A medium-sized computer (PDP-7) will be used with random access audio units, cathode ray tubes, typewriters, Rand tablets (for graphic pattern detection), a touch-sensitive display, and a manipulation board (See Glaser et al., 1964 for details on these devices). Research is to be directed toward the refinement and definition of interface equipment.

U. S. Air Force Decision Sciences Laboratory

In Massachusetts, Shuford and his associates (Baker, 1965; Shuford, 1965) are using CAI equipment to quantify confidence in S's decisions. Multiple-choice alternatives are presented on an oscilloscope to the student who may express his degree of certainty as to the correct answer by increasing or decreasing the length of the bars on a bar graph associated with each alternative. He does this by pointing the light pen at the alternatives for varying amounts of time, while the bars grow or shrink to the chosen probability levels of certainty. Ultimately these researchers expect to program messages appropriate to the advances made by a student in the reduction of uncertainty of a particular concept. Early results indicate that the use of the "degree of certainty" in weighting achievement responses substantially increases the reliability of such measures.

Northern Westchester County Board of Cooperative Educational Services

Under the direction of Richard Wing (1964), CAI programs have been developed to teach sixth graders some basic economic principles by having them portray a ruler's son in various historical periods. The student by making economic decisions, learns the principles involved.

Programs have also been developed in biology, elementary science, and other areas for use in local schools (Wing, 1965).

John Hopkins University: Department of Social Relations

Simulated real-life situations have been developed as games and are presently being adapted to a CAI system to allow secondary school students to play roles in society with which he might otherwise remain unfamiliar. For example, in the legislative game (Boocock and Coleman, 1965: Coleman et al., 1964) S plays a legislator who must try to pass or defeat bills in accordance with his constituents' wishes. Others are a career game and a community disaster game.

Rutgers University: Edison Responsive Environment

Moore's (1965) responsive environment is a device for research in complex learning which was developed to "can the Hawthorne effect." It has so far been used mostly in teaching young children to read in the following manner. Children are allowed to explore letters by typing: the machine, through a random-access tape recorder, then pronounces each letter typed. Amazing success has been reported

(Pines, 1965) in teaching children to learn to read and in helping autistic children to respond more socially through this method of discovery learning.

University of Wisconsin: The Synnoetics Laboratory

Under the direction of Philip Lambert, the Synnoetics Laboratory is dedicated to the synthesis of CAI and learning systems for the future classroom. These goals are similar to those of SDC.

THE EFFECTIVENESS PROBLEM

The Effectiveness Problem in CAI focuses on the purpose of any given program. A program which is to teach German vocabulary must be judged in terms of the author's criteria for learning this vocabulary. Furthermore, comparison should be made with other methods of teaching to these criteria in order to judge the efficiency in terms of time and cost of the method. This, however, is a separate problem which will not be considered here.

Theoretical Considerations

Because a psychologist advocates a certain method of teaching does not necessarily imply that the espoused method is based upon uncontrovertible scientific principles. The psychologist, like other intelligent men (as Bugelski, 1964, points out), may simply have found a new approach to an old problem. Reading advertisements for programed texts and teaching machines and reading many technical reports of studies with programed instruction, however, could easily brainwash the naive observer into believing that scientific psychology has finally solved all the teaching, motivation, and individual difference problems which have plagued man for centuries. Nevertheless, there exists no theory of CAI from which we can deduce learning principles appropriate to the CAI situation. Is there such a theory in the broader body of programed learning literature?

Since Skinner (1954) gave programed learning its present impetus using techniques analogous to those used to shape the behavior of pigeons, it is not surprising that he and his colleagues have emphasized the scheduling of reinforcement for an emitted response. In practice this has led to the use of small-step linear programs with heavily prompted frame sequences, in which these prompts are assumed to become discriminated stimuli which set the occasion for S's response. Seeing that his response was correct is assumed to reinforce S's response, so that empirically there is an increased probability of that response occurring again in the presence of the discriminated stimulus. Some researchers (e.g., Lumsdaine, 1962) maintain that reinforcement is not necessary for these stimulus-response connections to be formed but, following Guthrie, only that the stimulus and response occur contiguously.[18]

If it were not sufficient to have two learning models clash in interpreting the same datum, Hilgard (1964) argues that cognitive theorists would interpret it in yet another way--namely, that a process, not a response, may be what is learned. The purpose of this discussion is not to take sides in the controversies of learning theory, but to emphasize with Hilgard (1964, pp. 136-137) that

> . . . advances made in programmed learning have been based very little upon a strict application of learning

[18] An interesting theoretical issue which has been raised is whether the proper paradigm for programed learning is classical, free operant, or controlled operant conditioning (see Lumsdaine, 1962, or Zeaman, 1959, for the arguments involved). Practically speaking, however, this issue has little if any bearing on actual programing practices, especially CAI practices, and a resolution will not be attempted here.

> theory, regardless of what devotees of the different theories may assert.

Is programed learning, then, just another gimmick being perpetrated on unsuspecting educators as a scientifically sound method of teaching? The answer lies in research on the advantages claimed for it.

> Programed instruction has been based on four basic tenets that are assumed to be significant for learning: 1) The subject matter is systematically presented in small bits to the student, who is required to 2) become an active participant in the learning situation by constructing an answer to a question; 3) he receives immediate information about the quality of that response; 4) then he continues at his own rate to the next frame. (Dick, 1965, p. 41)

Research on all of these points is inconclusive (examples of studies of these assumptions can be found in DeCecco, 1964, and Lumsdaine and Glaser, 1960); by no means are findings sufficient to provide an authoritative formula for programed learning.

The conclusions to be drawn from this brief digression into the theoretical and research basis of programmed instruction is that there is no comprehensive theoretical base for it. This may help to explain why many of the studies have attempted merely to demonstrate the superiority of one method or programing arrangement over another. Parametric investigations of theoretically important variables have seldom been undertaken with the result that the major portion of the vast, expanding literature on programed learning is not amenable to incorporation into a theoretical framework (if one should be devised).

Task Specificity

Even if there were systematic data collected in programed learning, generalizability to CAI cannot be assumed without replication of studies The following three examples indicate the difficulties involved in generalizing the results of non-CAI studies to CAI systems

Licklider (1962) found that poor typists learned more rapidly when they responded implicitly (when they just pushed a button telling the computer to go on) than when they responded explicitly (when they typed the response), while good typists showed no difference in learning rate between implicit and explicit responding.

Silberman et al. (1961) found that Ss exposed to a branching technique (using a textbook format) had higher criterior test scores than Ss who received a fixed-sequence treatment. When a similar program was written for CAI there was no difference between the branched Ss and fixed-sequence Ss. A subsequent study (Coulson et al., 1962) indicated that branching based solely on the criterion of errors (the criterion used in the Silberman et al. study) is not sufficient, but must be augmented by S's self-evaluation and special diagnostic items.

A final, more subtle CAI-specific phenomenon is related to the oft-stated notion that CAI is student-paced. Wodtke, Mitzel, and Brown (1965) reported that students find the machine "fast" since it presents the next question immediately upon entry of the correct response to the previous frame.

On the basis of these examples it seems necessary to warn against widespread adoption of "principles" of programing discovered in extra-CAI research without replication in a CAI setting.

Individual Differences

Although it was indicated earlier that CAI systems could be programed to adapt to individual differences, enthusiasm for the widespread adoption of such a practice should be tempered by some realistic considerations. First and most obvious, the trite principle of teaching that one should " 'provide for individual differences' needs to be qualified with the specific conditions for its accomplishment" (Silberman et al., 1961, p. 171). There are many varieties of individual differences, but it is doubtful that there will be no differences in what is learned from a program simply by allowing Ss to proceed at their own rates or generate their own sequences of items. The time has come to specify what it means to "provide for individual differences" and what behavioral effects the "provision" will have.

A second consideration follows from the first. A systematic classification of individual difference variables, such as that in Fry (1963), is needed. But even more important are the relationships of such variables to the parameters of learning which are almost completely unknown. No matter how many scores we have on an individual (from personality inventories, achievement batteries, attitude questionnaires, socio-economic status, past educational history, etc.), they will be worthless in selecting the type of instruction this individual should receive unless these scores are predictive of some educational performance!

The elimination of individual differences (aside from time to mastery) in learning any given amount of material has been touted as a major advantage of CAI. The ungraded classroom and marking systems where grades are reported not on how much the student has learned, but on how far he has progressed through a course (e.g., see Skinner, 1958) are frequently foreseen as logical effects of programed instruction, especially CAI This introduces a third consideration, however. There is a good deal of research which suggests that rats, kindergarten children, and college students can all learn a discrimination task; but great differences are found in transfer depending upon S's verbal ability (Kendler, 1959; Kendler and Kendler, 1962) The implication for education from this research is that <u>it is unrealistic to expect any teaching method to eliminate individual differences</u>! The subtle influences of directions and mental set virtually assure us that Ss will attend to different stimuli in the learning situation And if by chance there are no differences among Ss in any given task, our measurement of the learning is suspect. For example, it may be that there was a ceiling effect on the criterion test; or we have failed to measure the differential abilities to transfer to new tasks, which in the long run is the goal of education anyway!

Finally, and most crucial, although it is sanctioned by the Zeitgeist to "adapt to individual differences," such adaptation must be demonstrated to be superior to teaching aimed at the mean of the group. This problem was clearly foreseen eleven years ago by Cronbach (1954, pp. 32-33):

> If a sample is divided into groups, using fixed cutting scores, the extent to which treatment for the groups should be differentiated depends on the validity of the placement test. If the information has zero validity, utility is maximized when we teach all sections in the manner suited to the average of the population. As validity increases, the treatments given the sections

> may differ more; but no matter how valid the test, there is an optimum degree of differentiation of treatment. If treatment is differentiated beyond this point, the benefit from sectioning declines. Indeed, it is possible to differentiate treatments so radically that a <u>loss</u> in utility results from sectioning even though the test used has considerable validity.
>
> This analysis raises serious question as to whether we are right when we urge teachers to adapt to individual differences. If the teacher has a standard plan, well fitted to the average of the group, he should hesitate to depart from it. Marked alteration of the plan to fit individuals appears to be advisable only when individual differences are validly assessed and their implications for treatment clear.

Few psychologists would maintain that we can validly assess any given individual differences; fewer still would recommend an educational treatment based on that assessment. Until parametric investigations of these individual difference variables are undertaken in CAI settings to make clear their educational implications, programing energy might best be expanded in the development of one good program aimed at the mean of the population who will use the program. Meehl (1954) came to a similar conclusion in regard to the clinical vs. actuarial prediction controversy.

For those who would object that this procedure is wasting the special powers of the computer to make on-line branching decisions, two points should be raised. First, it has yet to be demonstrated that branching sequences which are unique to criteria based on individual differences produce superior learning to some other simpler remedial technique, such as repetition of the difficult frame sequences. Second, the burden of proof rests with those who would replace existing teaching techniques with CAI systems. Thus, if it is claimed that adapting to individual differences through CAI would improve some aspect of learning, then parametric studies of variables deemed important should be undertaken. Yet studies of this sort are almost nonexistent. Almost all 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.

Other Effectiveness Issues

(1) To compare adequately the effectiveness of an instructional program on different students, control must be maintained over their prior experience with the concepts to be taught. This is difficult to accomplish with most subject matter, since students generally have some knowledge--more than they realize--about any given area (Mager and Clark, 1963). One solution to this problem might be to use invented material in the program (e.g., the imaginary science of Zenograde Systems used by Merrill, 1964) or else to use standardized materials such as paired-associates (as did Licklider, 1962). Use of such materials, however, may limit the generalizability of the results to education.

One solution to this perennial problem might be longer range experiments.[19] Variables which are posited to be important educationally could be explored first with standardized materials. When the effects of this variable are known in this laboratory situation, the experimenter will then be in a better position to make predictions of the effects of that variable in the more complex teaching program.

[19] Cronbach (1965) gives an excellent discussion of the necessity of long term experiments in education.

A research program of this sort would be another way for the educational researcher to establish construct validity.

(2) The criteria of learning are also a problem. Some of the measures which have been used have been error rate, response latency, per cent improvement from pretest to posttest, time to learn, retention scores, and transfer scores. In many cases one measure is not predictive of another (Gagné and Dick, 1962). Again, research may have to be directed to the interactions of subject-matter, type of program, and individual differences to resolve such inconsistencies.

(3) Motivation is a continuing problem in learning theory and remains so in CAI. It has been suggested that the "Hawthorne Effect" may be operating in the highly atypical CAI research laboratories (Dick, 1965). This may help to account for the generally favorable attitudes of students found by Wodtke et al. (1965); final evaluation of attitudes and their relationships to course performance will have to wait until more students work with CAI for longer periods of time (Pressey, 1959).

Summary

The question "How effective is a CAI program in producing the desired behavior change?" has been shown to be quite difficult to answer. Controversy rages over the theoretical bases of learning, criteria of learning, measurement of learning, experimental methodology and generalizability of studies, and individual difference variables as these affect student performance in CAI. The suggested approach to the ultimate solution (they will not be solved in one study) of these problems is to plan long-range parametric investigations of theoretically important variables with representative samples of the populations of Ss and materials to which the results are expected to be generalized.

DISCUSSION

It has been pointed out repeatedly that the present costs of CAI are prohibitive for all uses except research. The section on current CAI systems, however, has indicated that quite a few groups across the United States (and it is unlikely that they have all been identified in this paper) are very concerned with more than "pure" research. Indeed, it is clearly implied that these systems are expected to be operable in the near future. To keep costs down, Coulson (1963) suggested that the computer could be used during normal school hours for instruction for large numbers of students, counseling, and displays for teachers and administrators. At night the same machine could perform the routine processing of payrolls, attendance records, cost accounts, and other administrative duties.[20]

More important obstacles than costs must be surmounted, however. One of these is the negative attitude of many teachers toward programed instruction. Although it is almost a cliché that teachers will not

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[20]There is a great deal of activity in the development of "extra-curricular" uses of the computer. For example, in the area of counseling, Cooley (1964) recommended increased use of computers to obtain and collate information on students as an aid to overburdened guidance counselors. Carter and Silberman (1965) at SDC have, in fact, begun to develop such a program. At Penn State, Impellitteri (1965) is launching a program designed ultimately to use a CAI system to present students with information concerning vocations relevant to a student's interests. In the area of computerizing many administrative functions, the Iowa Educational Information Center (Marker, 1965) has developed a system (CARDPAC) to process educational information more easily and quickly.

be replaced by programed instruction, but that they will be "elevated" to having a motivating function, the teacher's point of view should be considered for a moment (Rabinowitz and Mitzel, 1962, p. 135):

> Educational functions are not, in practice, fragmented, and it is therefore difficult for teachers to see just how they will go about being creative in a classroom where subject matter is taught by programed materials.

This, coupled with the threat of the predicted new profession of "teaching engineers," a maximum of clerks and administrators, and a minimum of teachers doing the highest thinking and training (Ramo, 1957), would be expected to raise the anxiety level of all but a few teachers. It is possibly this type of unexpected side effect which Atkyns (1964) warns about.

Another problem is the rush to "mechanize" education prematurely. Glaser (1960) and Lumsdaine and Glaser (1960) warned that hardware production is way ahead of program production. Likewise, neither of these two areas (the Technical and Semantic) should be allowed to develop faster than the psychological principles on which this technology is based (Melton, 1960). Or, in Skinner's (1963, p. 168) words,

> The "mechanizing of education" has been taken literally in the sense of doing by machine what was formerly done by people. Some of the so-called computer-based teaching machines are designed simply to duplicate the behavior of teachers. . .What is needed. . .is an analysis of the functions to be served, followed by the design of appropriate equipment. Nothing we now know about the learning process calls for very elaborate instrumentation.

It is not necessary to agree with Skinner that elaborate instrumentation is unnecessary; on the other hand, where elaborate instrumentation is advocated (as it is in CAI systems), its need should be justified. Justification, however, does not consist of citing historical maxims, such as "teachers should adapt to individual differences." Rather it consists of experimental demonstrations of the increased effectiveness of teaching with this instrumentation certain courses to certain students under specified conditions.

At the recent American Psychological Association Convention, Coulson (1965b) stated that most of the remarks of the CAI symposium panel members could have been made five years ago. What worse indictment could be made of the research emphasis in CAI! The Technical Problem is virtually solved in the sense that more equipment is available with faster operating speeds than the educator knows how to use. The Semantic Problem is being solved with the development of languages which allow courses to be programed relatively easily. What kinds of programs to write in order to use the equipment <u>effectively</u> is, nevertheless, an almost untouched problem. We need, as Coulson (1965b) said, a model of the student. We have all kinds of flow charts for decision strategies, but how these affect students is almost completely unknown.

Parametric studies of theoretically important variables must be undertaken. The few experimental studies that were done seem to have been of the trial-and-error variety, leading to little progress through one generation of CAI systems. A suggested experimental approach is to take a current model of school learning, e.g., Carroll's (1963) model, and engage in a series of studies to test some of these notions in CAI. Conveniently, most of Carroll's variables are time-dependent measures, which can easily be explored in a CAI system. Thus, one series of studies might explore the conditions under which high aptitude Ss (i.e., those Ss who need small amounts of time to learn a given subject matter) learn a given set of concepts best, varying the opportunity (time allowed for learning).

I am not necessarily advocating Carroll's over any other model of school learning. I am, however, suggesting a feasible approach to the solution of the Effectiveness Problem. Indeed, some approach similar to this must be undertaken if we are to avoid hearing at the 1970 APA convention that "most of the remarks made here today could have been made _ten_ years ago."

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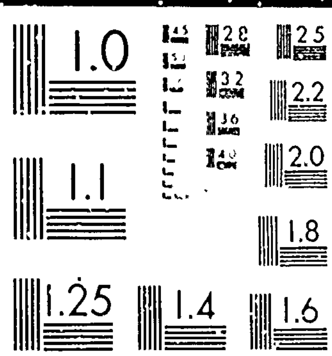
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