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ABSTRACT

Activities conducted during the period January 1966-June 1966 as part of the Pennsylvania State University computer-assisted instruction (CAI) project are reported. The objectives of the project are described in a previous document (IR 000 511). This report first provides information on the physical facilities and equipment used in this stage of the project. Next, the development of CAI course materials for technical education is described; a summary of all course materials developed, tested and revised is given, followed by details about course sequences in engineering science, technical mathematics, number sequences, and communications skills (spelling). Four categories of research on CAI and educational variables are also discussed. These involve: 1) feedback, prompting, and overt correction procedures in nonbranching CAI programs; 2) the efficiency of typewriter interface; 3) deficits in instructional time resulting from the typewriter interface; and 4) the effects of rote rule-learning on transfer of training. (Author/PB)

COMPUTER ASSISTED INSTRUCTION LABORATORY

COLLEGE OF EDUCATION · CHAMBERS BUILDING

THE PENNSYLVANIA STATE UNIVERSITY · UNIVERSITY PARK, PA.

EXPERIMENTATION WITH COMPUTER-ASSISTED INSTRUCTION IN TECHNICAL EDUCATION

SEMI-ANNUAL PROGRESS REPORT

JUNE 30, 1968

BEST COPY AVAILABLE

Note to accompany the Penn State Documents,

In order to have the entire collection of reports generated by the Computer Assisted Instruction Lab. at Penn State University included in the ERIC archives, the ERIC Clearinghouse on Educational Media and Technology was asked by Penn State to input the material. We are therefore including some documents which may be several years old. Also, so that our bibliographic information will conform with Penn State's, we have occasionally changed the title somewhat, or added information that may not be on the title page. Two of the documents in the CARE (Computer Assisted Remedial Education) collection were transferred to ERIC/EC to abstract. They are Report Number R-36 and Report Number R-50.

Jacklyn Carroll / ERIC IR

ED 089787

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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June 30, 1966

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CHAPTER 1

INTRODUCTION

This report spans the second six months of the operation (January 1, 1966 to June 30, 1966) 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.

Continuous 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 period covered by this report. The second section describes the progress which has been made in the development and evaluation of technical education courses for computer-assisted instruction. The final section contains several reports of research on variables related to computer-assisted instruction.

CHAPTER II

PHYSICAL FACILITIES AND EQUIPMENT

Physical Facilities. The project has now been almost completely moved into its new remodeled quarters. The new facility is extremely well suited to the needs of the project and its staff. Four new student terminals have recently been installed in four separate sound-proofed and air-conditioned rooms. The Laboratory office space easily accommodates the staff of the project. Office furniture and equipment made available from the University's own resources was installed in January, 1966.

Equipment. During the past six months the project continued to utilize two student terminals connected by means of dedicated long-distance telephone lines to the IBM 7010-1448 computer system at the Thomas J. Watson Research Center, IBM Corporation, Yorktown Heights, New York. Under our contract, IBM has been supplying 64 hours of terminal time per week, compiler course listings, and student record summaries. Our contract with IBM for these services terminates July 15, 1966.

During the past six months, conversion to Penn State's IBM 1410 computer system has been completed. This system is now operational and courses are being run successfully on this system. Beginning July 15, 1966, this system will control the four student terminals in the Laboratory, two additional terminals located at the Williamsport Area Community College, and two terminals located at Penn State's Commonwealth Campus in Altoona. The four student terminals in the field are presently being installed and will be available for student instruction by mid-July. Students enrolled at these two schools will be used for research and evaluation of our CAI courses in technical education during the summer.

CHAPTER III

DEVELOPMENT OF CAI COURSE MATERIALS IN TECHNICAL EDUCATION

Summary of All Course Materials Developed, Tested, and Revised

During the first three months of the project, July 1, 1965, through December 31, 1965, course authors were involved in learning the Coursewriter language. Initial course segments were developed in the three areas--communications skills, technical mathematics, and engineering science. After the first introduction to actual writing of courses using Coursewriter language, authors devoted time to revising and augmenting current courses, and incorporating the added functions required for programing slides and tapes into existing course segments. New functions using Coursewriter language were also developed by IBM's T. J. Watson Research Center, and authors included these new functions in the course segments.

The course segments prepared while the authors were concurrently learning Coursewriter language and its applications, were as follows:

Engineering Science	Technical Mathematics	Communications Skills
Introduction to Physics	Metric System	Spelling Rules
Working with Units	Calculus	
Scientific Notation		
Basic Magnetism		
Atom		

Table 3.1 represents an accumulative summary of all CAI course segments developed on the project as of June 30, 1966. The table indicates the extent to which each course segment utilizes audio-visual communication, static displays, the number of students who have taken the course to date, the total number of hours of student instruction, the length of each course segment estimated by the average time taken per student to complete instruction, and a column indicating whether the course segment has been revised following the examination of student performance on the course.

Table 3.1

Summary of All Course Materials
Developed, Tested, and Revised
as of June 30, 1966

Course	No. of Slides	No. of Tape Messages	No. of Static Displays	No. of Students	Total Time hrs/mins	Est. Avg. Student Time hrs/mins	Revised following evaluation
<u>Technical Mathematics</u>							
Number Systems	--	--	4	1	3	3	no
Metric System	3	--	--	4	4	1	yes
Significant Figures	9	2	--	5	9	1 45	yes
Introduction to Mathematical Problem Solving	--	--	--	3	3	1	yes
Kinematics and Calculus	8	11	--	6	4	40	yes
Vector Analysis	32	--	--	--	--	3 30	no
Trigonometry	--	--	27	7	9*	3 30	yes
Printing Calculator	3	3	4	--	--	--	no
Significant Figures1	--	--	7	14	22 30	1 30	yes
[1](Significant Figures100	--	--	7	11	12	1	yes
(Significant Figures200	--	--	7	11	15	1 15	yes
<u>Engineering Science</u>							
Introduction to Physics	10	6	--	2	1 45	52	yes
Working with Units	9	2	--	13	17	83	yes
[2](flbr	--	--	--	2	2 30	1 15	yes
(flcr	--	--	--	26	29 45	68	yes
(flsk	--	--	--	20	18	52	yes

[1] See page 54 for explanation of these course adaptations.

[2] See page 36 for explanation of these course adaptations.

*Represents student instruction time to cover one segment only.

Course	No. of Slides	No. of Tape Messages	No. of Static Displays	No. of Students	Total Time hrs/mins	Est. Avg. Student Time hrs/mins	Revised following evaluation
Scientific Notation	25	--	--	4	4	1	yes
Atom	20	19	--	14	12 30	1	yes
Basic Magnetism	12	6	--	2	2 30	4 15	yes
Optics, Part I	28	--	--	--	--	--	no
<u>Communications Skills</u>							
Spelling:							
Rules	--	--	--	9	13 30	1 30	yes
Rules Test	--	15	--	8	12	1 30	yes
Diagnostic Test	--	37	--	--	--	--	no
Vocabulary	7	12	--	8	12	1 30	yes
Introduction	5	3	--	11	15 30	1 30	yes
Plurals	--	--	--	--	--	--	--
Suffixes	--	--	--	--	--	--	--
Compounds	--	--	--	--	--	--	--
Words with <u>i</u> - <u>e</u>	--	--	--	--	--	--	--
Words with <u>e</u> - <u>y</u>	1	1	--	--	--	--	--
Syllables	--	14	--	--	--	--	--
Discrimination	--	--	--	--	--	--	--
Homonyms	--	--	--	--	--	--	--

Course segments in process of being written as of June 30, 1966; not in computer storage.

Electrostatics

Optics, Part II

Atomic Structure

Heat and Thermodynamics

Use of Micrometer and Vernier Caliper

Electronics

Engineering Science

Joe K. Ritchey and David A. Gilman

Material has been prepared for instruction in the following areas of engineering science: (1) optics, (2) heat and thermodynamics, (3) atomic structure, (4) electrostatics, (5) electronics, and (6) measurement by use of vernier caliper and micrometer. However, due to difficulties in scheduling and equipment problems, the course materials are not stored in a computer as yet.

A serious attempt is being made to prepare materials specifically for students in technical education and to follow the guidelines for technical education suggested by W. J. Schill and J. P. Arnold in Curricula Content for Six Technologies.

In programming the first section of the electrical portion, of the physics curriculum, a different strategy was employed. The course segments programmed to date dispersed instructional material with questions. In this segment the instructional material was programmed in unit blocks, each block followed by questions pertaining to the preceding unit of instructional material.

The first electrical course, electrostatics, was divided into the following units and programmed in this manner:

1. Electrification
2. Kinds of Electrical Charges
3. Conductors-Semiconductors-Insulators
4. Electroscope
5. Coulomb's Law
6. Electrostatic Apparatus
7. Electric Fields
8. Electrostatic Facts

The course material forms an introduction to electrical fundamentals necessary for skilled workers and technicians in electricity and electronics. For example the knowledge will be basic to the study of capacitors, an important component of electrical and electronic equipment.

The change in programming method was instituted to see if (1) concentrated instructional material taking full advantage of the program, slide projector and tape recorder could become an improved programming technique and (2) to determine if this method would be more beneficial in terms of remedial branching.

The last portion of the program is a series of questions from each unit covered. Based upon an incorrect answer the student is branched back to review the instructional unit again and returned to the question for a second response. In this manner the student reviews the unit material and does not repeat text questions.

Included in this program is a controlled feedback feature based upon the number of student responses. In previous programming, the feedback following a correct answer was the same regardless of the number of responses made by the student. For example, the feedback of "Very Good" could be typed after the student had exhausted several hints, the last one of which gave him the correct answer followed by instructions to type the correct answer. This must reduce the effectiveness of the feedback process. With controlled feedback, the most rewarding feedback is reserved for the first correct response otherwise the feedback remains the same if more than one attempt is necessary. In this program the feedback "Right" is typed if more than one response is necessary to answer the question correctly.

A possibility for a future program using this method could include a student option or diagnostic questions prior to a unit in order to branch to the questions on that unit or to the next instructional unit.

<u>Sample Program</u>

LABEL	OPR MODE	ARGUMENT
ad-5	rd	Scientific Notation is a method using powers of ten to facilitate handling large and small numbers. Scientific notation may also be called standard form or slide rule form.
	fn	slide//8

<u>Slide 8</u>

Given a number to be written in scientific notation write the number as the product of a number between 1 and 10 and a power of ten. The number should be greater than or equal to 1, and less than 10.

---

fn	wait//20
fn	slide//9

<u>Slide 9</u>

The number 6,580 written in scientific notation

6.58	x	10^3
Number	Product	Power of ten

---

rd	Example. Write 5,680 in scientific notation. 5.68 is a number between 1 and 10. $5.68 \times 10^3 = 5{,}680$ in scientific notation. 0.568 would have been a number less than 1 and 56.8 would have been a number greater than 10. 5.68 is the only way to write the original number as a number between 1 and 10.
qu	What part of the number <u>6</u>8,400,000 must be written as a number between 1 and 10? (Do not write the number in scientific notation.)
nx	
fn	kw//3
wa	\$ 6.84 \$x\$ 10^7
ty	Wrong. Write 68,400,000 as a number between 1 and 10. Do not write the number in scientific notation.

It is anticipated that some students may not follow instructions and may proceed immediately to write the number in scientific notation without first taking advantage of important instruction.

nx	
fn	ic//3
ca	<u>6</u>.8

ty	Correct

The ic function will accept any answer so long as the first three characters are 6, ., and 8.

nx	
fn	ic//3
wa	.68
ty	Wrong. The number must be greater than 1.
ad	1//c6

Many students will make the mistake of responding with a number less than one. The student's error rate is stored in counter 6 (c6).

nx	
fn	ic//3
wa	68.
ty	Wrong. The number should be less than 10.

If the student does not understand that the number must be less than 10, he receives appropriate feedback.

ad	1//c6
un	Try again. You must type a number between 1.0 and 9.9.
ad	1//c6
un	The correct answer is 6.8.
ad	1//c6
br	help

Students unable to get the correct response after two attempts are branched to remedial instruction.

qu Write the following number in scientific notation. 5,280

Technical Mathematics

David A. Gilman and Nancy Harvilchuck

The major activity of the technical mathematics program has been course preparation. A special attempt is being made to prepare mathematics course material specifically for technical students in accordance with the guidelines listed by William Schill and Joseph Arnold in Curricula Content for Six Technologies.

A trigonometry course, roughly equivalent to two months of classroom instruction has been prepared. Also, a comprehensive course in vector algebra has been prepared and is now being evaluated.

Conferences with mathematics professors at the Altoona Campus of Penn State and mathematics instructors at Williamsport Area Community College have been useful in the development of objectives for our mathematics programs.

Experimental studies which are planned include studies which will attempt to ascertain if it is better for a student to choose his own sequence of instruction in a mathematics program or if the sequence of instruction should be fixed and determined by the course author as he writes the program.

The segment of the program which follows was taken from a program in trigonometry. The segment deals with the law of sines and the law of cosines. Knowledge of these laws is necessary for the analysis of force vectors, for the determination of velocity components, for finding the components of an alternating current, and for other tasks required in technical occupations.

Sample Program

LABEL	OPR MODE	ARGUMENT
jb-600	rd	
	ty	The Law of Sines and The Law of Cosines
	ty	The trigonometric functions are used to solve right triangles. However, many triangles have no right angles. If a triangle has no right angle, special rules are needed to find its sides and angles.

fn slide//20

Slide 20

The Law of Sines and the Law of Cosines

LAW OF SINES

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

LAW OF COSINES

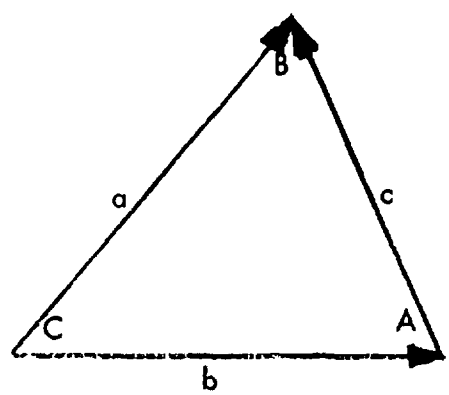
General Form:

$$c = \sqrt{a^2 + b^2 - 2ab \cos C}$$

Alternate Forms:

$$a = \sqrt{b^2 + c^2 - 2bc \cos A}$$

$$b = \sqrt{a^2 + c^2 - 2ac \cos B}$$



---

jb-630 qu You could find any angle by using the law of cosines if you knew _________ sides.

nx

fn kw//1

wa twoTwo$ 2 $ 2.

ty No. If side a and b are known, one could not find angle c without knowing side c also. Try again.

The computer first checks to see if the student answered incorrectly. He is then given a short explanation to indicate why he is wrong.

ld 1//s6

When a student has difficulty, it is noted by loading switch 6. Now the computer waits until the student makes another response.

	nx	
	fn	kw//1
	ca	$hree$3
	ty	Very good
	br	jb-620//s6//1

*This branch sends the student who had difficulty with this problem to a section for review. Students who answer correctly the first time move ahead in the program.**

un Examine the general formula for the law of cosines. To find the angle, one would do the following:

ty Square both sides first--

$$c^2 = a^2 + b^2 - 2ab \cos C$$

$$\text{Cos } C = \frac{c^2 - (a^2 + b^2)}{-2ab}$$

$$\text{Cos } C = \frac{a^2 + b^2 - c^2}{2ab}$$

ty Therefore all three sides must be known to solve the problem.

ty Make sure that you understand, then press EOB

br jb-620

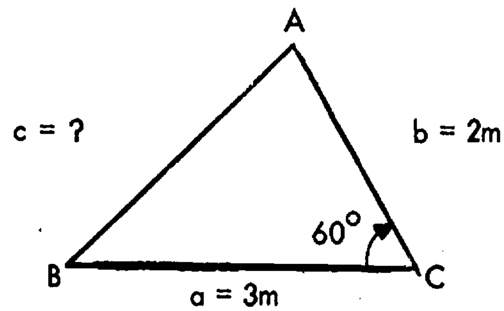
This branch gives the student a similar problem to make sure that the concept is clear. After working several problems with 3 sides given, the student is given other unknowns.

jb-640	rd	
	fn	slide//23

---

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

Slide 23 PROBLEM



---

jb-642	qu	a = 3m
		b = 2m
		C = 60 degrees
		Find side c.
	nx	
	fn	lim
	ca	2.5//2.7

The limit function will accept all numbers greater than or equal to 2.5 but less than 2.7.

ty	Correct. The exact answer is 2.6 meters.
un	Wrong. Are you using the Law of Cosines this way? $c^2 = a^2 + b^2 - 2ab \cos C$ Type another answer.

Using hints, the author can guide the student who is having difficulty.

un

$$c^2 = (3m)^2 + (2m)^2 - (2 \times 3m \times 2m \times .500)$$

$$c^2 = 6.8m^2$$

c = __________

un The correct answer is 2.6m. Type 2.6m.

The last "un" tells the student the correct answer. In this way, the student who may not be able to find the square root of 6.8 will still be able to proceed.

REFERENCE

Schill, William John and Arnold, Joseph Paul. Curricula Content for Six Technologies. Bureau of Educational Research and the Department of Vocational and Technical Education, University of Illinois, Urbana, 1965.

Number Systems

Harold Sands

A program entitled Number Systems was written for the purpose of investigating techniques of developing computerized instructional materials in the area of mathematics. The program consists of approximately 840 Coursewriter statements and will take an estimated 3 hours for a student to complete.

The objectives of this program are as follows:

Main Objective

To have students acquire the ability to convert a number from one number system to another. For example: 231 (base five) = ______ (base ten)

Sub-Objectives

To recognize for any symbol in a number its equivalent expression containing a coefficient, base, and exponent; an example of this would be to recognize $2(5^2)$ as the equivalent of the 2 in 231 (base five).

To recognize the correct expanded form of any number; an example of this would be to recognize $4(9^1) + 1(9^0)$ as the equivalent of 41 (base nine).

To recognize the correct numerical expression for a verbal statement. An example of this would be to recognize "20" as equivalent to "two groups of the base in any number system."

The programming strategy used is a slight departure from most of the strategies used with Coursewriter. The major criteria for branching is not the type of error response but in the amount of practice required to achieve mastery within sections of the program. Also, an attempt has been made to keep error rate at a minimum. Students who do make errors are not required to type the correct answer, but are given an explanation of the correct solution and are automatically branched to the next item.

The program is currently operational on the computer, however, no educational evaluation has as yet been made. Information is not available on the effectiveness of the program at this time, but student evaluation of the program is scheduled for the near future.

CAI Communication Skills

Harriett A. Hogan and David C. Bjorkquist

Efforts to develop CAI courses in the communication skills have been concentrated in the improvement of spelling. Teachers of technical students have indicated the need for such programs and the objectivity of the subject matter lends itself well to the exploration of programming schemes. Programs in other communication skills will succeed the spelling programs.

The purposes of the spelling programs are to evaluate the spelling competencies of students preparing to be technicians and to provide remedial instruction in nine areas of spelling as needed by each individual student. Major emphasis in each spelling program is directed toward the utilization of the decision making capacity of the computer to individualize instruction and toward the optimum use of the audio and visual equipment associated with the computer terminals.

In Figure 3.1 a diagram of the complete spelling program is shown.

Orientation

Word Study

Diagnostic Test

Remedial Programs*

1. Plurals
2. Homonyms
3. Contractions and hyphenated words
4. ie and ei combinations
5. Double consonants
6. Suffixes
7. E and y endings
8. Visual discrimination
9. "Demons"

Proofreading

Achievement Test

Fig. 3.1 Diagram of CAI Spelling Program

*Students are branched to appropriate remedial programs on the basis of their Diagnostic Test performance before proceeding to Proofreading.

At the present time completed course chapters include an orientation to the Selectric typewriter, tape recorder and photographic slide computer outputs, a word study unit, the *diagnostic test* and six of the *nine remedial segments of the course. In addition to* the three remaining remedial programs to be completed a proofreading exercise and an achievement test will be prepared.

The word study unit emphasizes the importance of systematic word study in the improvement of spelling. Students are encouraged to look at each word, pronounce it and then write it. Instruction in dividing words into syllables is included. Word study also includes examining words for "trouble spots" such as silent letters, difficult vowel combinations and unphonetic sounds.

The diagnostic test is used to evaluate each student's spelling performance in nine problem areas. Five items in each of the nine areas are included in the 37 word diagnostic test. This is accomplished by using some words for more than one purpose. For example, in the word perceive, if the first syllable is spelled incorrectly, it is tallied as a prefix-suffix error, if the ei combination is reversed, an ei-ie error is tallied. If a student makes two or more errors of one type he is branched to the appropriate remedial program. Unanticipated responses are tallied as errors which will branch the student to the remedial program on syllables.

The objectives of the Proofreading Unit will be to emphasize the importance of proofreading written work in eliminating spelling errors and to improve the spelling of words in context. A segment of a technical report such as might be prepared by a technician will be displayed to the student and he will identify and correct misspelled words in it.

The Achievement Test, like the Diagnostic Test will be made up of words containing nine types of spelling problems. Difficulty of the two tests will be equated so that change scores from Diagnostic to Achievement Test can be obtained.

Words used throughout the spelling program are selected from lists of most commonly used words and lists of technical words. The selection of words and the context in which they are used are intended to interest the technical student and to illustrate to him how spelling may be an occupational skill and important to him in his work as well as in general usage.

Evaluation of the chapters of the spelling program will focus on the productivity of the program segments measured by student spelling changes as related to variables such as length of instructional time, mode of presentation, concept loading of programmed segments, and programming sequence. Measures of learning, retention and transfer will be used to compare programming strategies for technical students of varying abilities and interests.

Sample Program

LABEL	OPR MODE	ARGUMENT
		*The following sequence is from the word study section of the spelling program.**
	rd	
	ty	It is easier to spell a word correctly when you pronounce it correctly. Often syllables are incorrectly added or omitted in pronunciation and then in writing. When you examine a new word note the syllables in the word; this should make the word easier to spell. Each sounded vowel represents a syllable.
	qu	A word can be divided into syl__bles.
		The typewriter backspaces and the student fills in the second syllable of the word.
	ca	la
	ty	Right. You have written the second syllable of the word syllables.
	wa	al
	ty	You turned the letters around. syl__bles
	un	syl la bles. Fill in the missing syl__bles.
		The student has made an unanticipated response and is given another opportunity to write the correct answer.

---

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

rd

ty Double letters often cause confusion in spelling. It is helpful to break the word into syllables. (A word containing double consonants is broken between the consonants.)

fn slide//5

Slide 5

committee

---

fn tape//7

Tape Message 7

committee

---

fn tape//8x

qu Look at the word on the screen. Type it in syllables. Use a slash / to break the word.

fn kw//3

ca $ com/$mit/$tee

The student's answer is checked for the three correct syllables. The $ is a delimiter used to separate the three parts of the keyword answer.

ty Very good

fn slide//6x

The next slide is positioned.

fn kw//3

wa $comm/$it/$tee

The student has broken the word into syllables incorrectly. The answer will not be accepted and he receives the following typeout.

ty	Break the word between the double m.
nx	
fn	kw//2
wa	$com/$mittee
ty	Break the word into three syllables. Break it between the double consonants.
un	Break the word into three syllables. Remember to break between the double consonants.
un	The word has three syllables. Break it between the double consonants.
un	com/mit/tee -- Type it correctly.
rd	
fn	slide//6

Slide 6

necessary

---

fn tape//8

Tape Message 8

necessary

---

fn tape//9x

qu	Examine the word which appears on the screen. Remember each sounded vowel represents a syllable. Type the word in syllables. Use a slash / between each syllable.
fn	kw//4
ca	$ nec/$es/$sar/$y
ty	Correct
fn	slide//7x
fn	kw//3
wa	$nec/$es/$sary
ty	The y is sounded as a separate syllable.
un	Type nec/es/sar/y

Evaluations of Instructional Programs

David A. Gilman

In the interest of ascertaining the effectiveness of instructional programs, student performance on the programs is being constantly evaluated. Several preliminary evaluations have already been completed. The first of these consisted of instruction involving six engineering technology students from the Altoona Campus of Penn State. These students received instruction in Units in Physics, the Metric System, Magnetism, and Scientific Notation. The students received instruction under the observation of the program's author, who observed the reactions and responses of the students to the program. These students had received previous instruction in physics and therefore had some previous understanding of the concepts taught in each of the programs. Their suggestions and reactions to the program were useful in revising the programs they tested and will help the authors in the planning of instructional strategy for future courses. The performance of these students is summarized in Table 3.2.

Table 3.2

Test Results, Engineering Technology Students

Student	Test Scores		Time	Responses to Program		
	Pre	Post	(minutes)	Attempts	Wrong	Percentage Wrong
1	14	19	59	32	8	25
2	20	25	55	35	11	32
3	24	27	62	34	10	29
4	27	28	52	36	12	33
5	27	28	47	24	0	0
6	22	25	54	34	10	29
Means	22.4	25.4	55	32.5	8.5	24.7

The second evaluation involved instruction in Working with Units to thirty business students from the State College Area Senior High School. None of the students had received [illegible] instruction in the use of units, and none had prior physics instruction.

The instruction took place under the observation of the program author. The program author did, at times, assist the student in the operation of the terminal equipment. However, no instruction was given the student other than that received by the student from the computer terminal. The instruction was entirely "stand alone" computer instruction.

The purposes of this evaluation were (1) to observe the instruction of students who had no prior knowledge of concepts taught, (2) to test learning gains by comparing scores on a pre-test with the scores on an identical posttest, and (3) to determine, by the use of a reaction inventory the student's opinions of CAI.

Table 3.3 shows the results for twenty-one students. The students' pre-test performance was extremely low. Prior to this instruction, most of the students had no idea of the meaning of "centimeter" or "kilogram" and none had knowledge of how units were used in working physics problems.

Table 3.3

Test Results, High School Students

	Test Scores					
Student	Pre	Post	Retention (6 weeks)	Time (minutes)	Attempts	Error
1	02	16	14	81	58	31
2	09	14	9	67	52	25
3	01	15	13	115	54	27
4	06	23	17	73	51	24
5	01	17	17	99	52	25
6	01	14	10	63	42	15
7	10	18	22	57	39	12
8	01	04	07	58	58	31
9	00	17	13	86	50	23
10	06	13	12	65	52	25
11	06	17	12	127	69	42
12	04	18	17	92	51	24
13	22	24	25	55	56	29
14	08	16	17	54	68	41
15	06	16	13	101	67	40
16	02	16	14	106	47	20
17	09	21	20	92	63	36
18	10	22	16	106	53	26
19	10	19	20	92	58	31
20	12	26	20	64	47	20
21	01	24	20	70	54	27
Means (N = 21)	5.19	17.6	15.6	172.3	54.3	27.3

After the students had received instruction at the terminal, averaging 82 minutes per student, the students achieved scores on a posttest which indicated considerable gain in achievement. At the conclusion of instruction, students were able to work problems involving physics units and understood the methods for multiplying, squaring, and cancelling units.

Most students indicated favorable reactions to this form of instruction. Many stated that they preferred CAI to conventional instruction.

Six weeks after the instruction, the students returned to the laboratory and a retention test was administered. Results of this test indicated that very little of the material learned by the students was forgotten. This suggests that CAI may be an excellent medium for presenting material when long term retention is desired.

Further experimentation is planned with the Units program. The present program contains considerable branching based on the student's understanding of specific topics. Revisions are now being made in the original program based upon the student performance data.

CHAPTER IV

RESEARCH ON CAI AND EDUCATIONAL VARIABLES

Feedback, Prompting, and Overt Correction Procedures in Nonbranching Computer Assisted Instruction Programs

David Alan Gilman

The obvious advantages of computer-assisted instruction (CAI) over conventional programmed texts are the branching and decision-making capabilities. The computer is able to evaluate the student's response and branch him to the next appropriate level of instruction. However, other possible advantages exist. The student may devote more attention to CAI than to conventional programmed texts because he is attracted to the material as it is typed to him or because of increased meditation. The mode of feedback and prompting may also be an important advantage for CAI. CAI ordinarily utilizes contingent feedback and prompting. The student who responds incorrectly is provided with an immediate evaluation of his answer, a statement as to why his answer is not correct, and a prompt to assist him in his next attempt to respond correctly. This process is repeated until the student overtly demonstrates a correct response. Students who respond correctly are informed that they are correct. In a linear programmed text, the feedback a student receives after a response is a statement which informs him what his response should have been. Students attempt each answer once and may proceed in the program without overtly demonstrating a correct response. In general, CAI provides much richer feedback, prompting, and response opportunities for the student than a more traditional programmed text.

If a student pays more attention to instruction from a CAI terminal than to programmed text instruction or profits more from contingent feedback than by reading the correct response, these advantages should manifest themselves in higher achievement or retention in groups taught by CAI.

The primary purpose of the present study was to compare an instructional program prepared by means of IBM's Coursewriter language for CAI presentation with a more conventional programmed text. The feedback, prompting, and correction procedures available in the Coursewriter language were expected to produce increased student motivation, attention, achievement, and retention over time. The branching and decision-making capability of CAI was not examined in the present study. This problem is to be examined in the next in a series of investigations of the learning efficiency of computer-based instruction.

Rationale

No teaching machine program and no conventional program represent a whole class, nor do the two differ in only one dimension. They differ in an indefinite number of ways. Holland (1966) states that the adequacy of any method of instruction can be changed by manipulating variables which are often subtle.

An evaluation of programmed text versus CAI involves careful planning to eliminate variables which would favor either treatment. It is obvious that it would be difficult to compare a linear programmed text with a branching CAI program, because the students receiving instruction using the respective programs would not, in fact, receive the same instruction. Thus, a comparison of teaching texts and CAI programs should be accomplished in the absence of branching.

The rationale for this study is divided into three sections as follows: (1) attention, (2) feedback, and (3) retention.

The attention-holding power of computer-assisted instruction. Dick (1965) indicated that CAI may provide a more stimulating learning situation than the repetitive type of instruction provided in many programmed texts. Wodtke (1965) suggested that a student might learn more efficiently by CAI because of the stimulus orienting power of the tele-communication devices such as the typewriter, slide projector, and tape recorder.

Wodtke (1965) reported two preliminary studies of two computer-assisted instruction programs in which little or no forgetting was observed; in one case after a one-week interval, and in the other case after a six-week interval. He suggests that there could be properties unique to CAI which facilitate retention. The "pin-ball machine effect" has been talked about by some writers. This phenomenon refers to the apparent tendency of computer-assisted instruction to facilitate high levels of attention to the instructional materials for long periods of time. In describing this effect, Wodtke suggests that these effects may be due to the novelty of the instructional method and may wear off after some time, or may be long lasting and result from certain properties of tutorial interaction which students find highly reinforcing.

However, Fordon (1965) states that machines designed to present material in small segments are not compatible with normal reading habits, since people read to get the essence of material, and the essence may be in one word three lines below where a student reads.

In a test of mastery, (Shurdak, 1965), 48 students at Columbia University learned a portion of Fortran by one of three methods, by computer, by programmed text, or by conventional text. There were no statistically significant differences in mean times to complete the course. The CAI group scored significantly higher than the other two groups on the criterion test. The difference between the other two groups was not statistically significant. The differences between groups was less marked for bright students. Shurdak calls his program a CAI program and diagrams contained in the report of his study illustrate that it contains some branching.

A related experiment which investigated the perceptual learning task of identifying nonverbal sounds (Swets, 1962; Swets et al., 1964), attempted to ascertain if there was a difference in learning whether Ss used a cathode ray terminal or typewriter terminal. Both studies found no significant differences in posttest scores between the groups taught by the two types of communication devices. The findings by Swets and a review by Holland (1961) affirm the conclusion by Stolurow and Davis (1966) as to the relative merits of teaching machines and programmed texts. After examining several studies, Stolurow and Davis conclude that the typical finding is that there is no difference in the effectiveness of a machine and a book.

Inconsistent findings exist concerning the instructional values derived from the attention compelling features of the typewriter terminal. If the terminal helps the student pay closer attention to the instructional program than does a programmed text, then the student who receives instruction from the terminal should learn more than one who receives instruction from a programmed text.

Feedback. Much consideration has been given to the relative merits of contingent feedback and prompting versus feedback which provides the student with a statement of the correct answer.

Klaus (1966) describes contingent feedback as a process whereby differentially applied reinforcement improves the quality of a response by shaping it to the desired degree of programming. Crowder's (1962) definition of programmable material requires that it be adaptable to contingent feedback.

"If we can say to the student (a) your answer is wrong, (b) this is what is wrong with your answer, (c) this is the feature of your answer that is wrong, (d) this is how you go about figuring out the correct answer, and (e) now try again; then we are dealing with programmable material."

Basically, contingent feedback is one characteristic of a stimulus centered program. In a stimulus centered program, emphasis is given to instances where the learner responds incorrectly. The student is then provided feedback to prompt him in an attempt to get the student to respond correctly. Annett (1964) suggests that responses in the programmed learning situation are not necessarily attempts at the correct answer, but may be attempts by the student to draw the answer from his environment.

In a response centered program, however, the appearance of a correct answer serves as a reinforcement only when the response is correct. Otherwise, the response is wasted. Since the response centered program can only cope with the correct answer (they alone are reinforced), it is essential that the student must make a minimum number of errors. When the response is correct, the knowledge of correct response feedback confirms the response; but when the response is incorrect, it does not.

After analyzing several studies, Holland (1960) states that there is difficulty in finding advantages for partial prompting. Holland concludes that if the subject does not know the correct answer, he might as well be told it.

The conflicting theories of reinforcement offered by the advocates of response-centered and stimulus-centered programs cause Klaus (1966) to formulate a feedback paradox.

"A learner who does select a correct answer in a stimulus-centered program is not given further explanation of that point. Instead, he is informed that he is correct and is introduced to new material, often with a positive statement of the desired answer. This seems to be precisely the technique used by response-centered programmers to reinforce a correct response. Similarly, when a learner provides an incorrect answer in a response-centered program, he is shown the correct answer. But, simple substitutes, such as the statement, "You are correct," should prove equally effective as a confirmation of the correct answer if the purpose of the correct answer is solely to provide reinforcement and not information."

The conflicting theories of reinforcement point to a need for ascertaining if there is merit in providing feedback contingent on the student's response, or if providing the student with the knowledge of the correct response is the more efficient technique.

Retention and learning. Some variations which are of little value in facilitating the amount learned or the rate of learning may prove to have a significant effect on retention. Wodtke (1965) hypothesizes that some instructional treatments may have effects on learning and retention similar to that of the variable-ratio reinforcement schedule of experimental psychology. Thus, one instructional treatment may produce relatively inefficient learning, as evidenced by immediate posttest scores. However, the same treatment may have a positive effect on retention, as measured by a delayed retention measure. For example, some effects associated with CAI, such as greater attention or contingent feedback, may not appear in measures of immediate achievement, but may facilitate long-term retention.

Brackbill et al. (1964) have obtained such results in an experiment comparing the effects of immediate versus delayed feedback. There were no significant differences on the tests of immediate retention, but significant differences were observed for one-day and seven-day retention measures in favor of a 10 second feedback delay.

It would seem logical that if a student's errors were specifically pointed out to him, as in the case of contingent feedback, he might remember his errors and thus be able to answer more questions correctly on a retention measure than could a learner who had received KCR feedback.

Likewise, if the typewriter terminal helps the student to focus attention on a task, a student who receives instruction at a terminal might retain the material better than a student who received instruction from a method requiring less focused attention.

Method

Subjects. The subjects were 66 ninth and tenth-grade students in the college preparatory curriculum at State College Junior High School. All were naive with respect to educational experimentation procedures and none had received instruction in physics. All Ss who began the experiment completed the experiment.

Materials. Three programmed courses were prepared. The subject of the three programs was dimensional analysis, or performing calculations involving units of measurement in working physics problems. The material of all three programs was identical with the following exceptions. The first program (CPF) was a CAI program utilizing contingent feedback and prompting. The second (KCR) was also a CAI program, but feedback consisted of the terminal typing the correct response two inches to the right of the student's response as in a typical programmed text. The third group (text) received instruction which contained material and feedback identical to the KCR program, but was presented by a programmed text, rather than by a terminal.

Equipment. CAI equipment used by groups CPF and KCR consisted of IBM 1050 terminals connected to an IBM 7010 computer. Instruction was teleprocessed a distance of 250 miles between the terminals, located at University Park, Pennsylvania, and the computer, located at Yorktown Heights, New York.

Tests. Three tests were constructed for the experiment. A pretest consisting of ten items was devised to ascertain whether or not Ss had prior knowledge of dimensional analysis.

Two parallel tests consisting of forty items were constructed. The two tests were identical, except that the numbers in the problems of the second test (to be used as a retention measure) were different from the numbers used on the first test (used as an immediate posttest).

The posttest and retention test contained items designed to measure both mastery and transfer. In an earlier pilot study, one of the parallel forty item tests yielded a KR-20 reliability of 0.86, an average item difficulty index of 0.52, a mean of 21.07, and an average item-total score correlation of 0.50.

Design. Subjects were randomly divided into three groups. The randomization was accomplished by the use of a shuffled stack of student data cards. Ss were pretested with the ten question pretest. No S answered more than 3 questions correctly and most answered all responses incorrectly.

Two of the groups received instruction by CAI programs. The first of these (CPF) received contingent feedback and prompting and students were required to answer the item correctly before proceeding. The second group (KCR) received instruct' n by means of a CAI program providing a statement of the correct response. The third g p (text) received instruction through a programmed text containing material and feedback identical to that of the KCR program. In all three groups, the instruction was completed in a single lesson.

All instruction was "stand alone" instruction in that no other instruction was provided other than the programmed course. There were no difficulties with any of the equipment used during the experiment and the CAI groups experienced no down time or delays.

Results

The mean scores of each group on pretest, posttest, and retention measure are presented in Table 4,1.

Table 4.1

Comparison of Mean Posttest, Retention Test, for On-line and Off-line Instruction in Dimensional Analysis

	Pre-test	Posttest	6-week retention
(A) Linear Programed text (off-line) (text n = 22)	1.06	20.6	17.0
(B) Linear Programed text (on-line) (KCR n = 22)	1.09	20.0	15.3
(C) Linear Coursewriter Program (on-line) (CPF n = 22)	0.91	21.9	17.9
(D) F Ratio	-	0.41	1.10
(E) Significance	n.s.	n.s.	n.s.

Table 4.1 gives a presentation of the means of the three groups. There are slight differences in the means of both immediate posttest measures favoring contingent feedback-p..mpting over knowledge of correct response feedback and favoring CAI over programmed

text. These small differences were not statistically significant ($p > .10$). Apparently neither type of feedback nor media of presentation was an important factor in the learning or retention of the material.

One important factor in programmed learning is the time required. Table 4.2 shows the mean times spent by students in the three programs.

Table 4.2

Comparison of Mean Instructional Time
for On-line and Off-line Instruction
in Dimensional Analysis

	CPF	KCR	Text
Instructional Time (Minutes)	68	52	42
F Ratio	16.17	($P < .001$)	

The differences in the means of the three groups were significant ($p < .001$). Clearly the terminal instruction required more time than instruction from a programmed text and programs utilizing CPF feedback required more instructional time than KCR feedback.

For a more detailed discussion of these findings see "Some Comments on the Efficiency of the Interface in Computer Assisted Instruction at the High School and College Levels" by K. H. Wodtke and D. A. Gilman.

Conclusions

The major conclusions of the study may be summarized as follows:

1) No differences in learning and retention were obtained for a CAI program which incorporated response-contingent feedback, prompting, and overt correction procedures on the part of the student when compared to a CAI program which simply typed the correct response following a student response and proceeded to the next frame.

2) No differences in learning and retention were obtained for a condition in which [illegible]structional program was administered by a teletypewriter communication device as

compared to a condition in which the material was presented by means of a programmed text.

3) The conditions in which instruction was presented by a CAI communication device took significantly more instructional time than the programmed text condition. This effect resulted from the relatively slow typeout rate of the typewriter in CAI.

The results of the present study appear to be consistent with the results of Swets (1962), Swets et al. (1964), and Stolurow and Davis (1966), but inconsistent with the results obtained by Shurdak, (1965). Shurdak (1965), however, employed an instructional program which contained branching to adapt to the individual learner, diagnostic and drill questions, and computer-controlled and optional review. Shurdak's more adaptive program probably accounts for the superiority of his computer-based instruction group over programmed and conventional text groups. The present study did not examine the branching question, but only compared different strategies for correcting student errors and providing feedback to the learner. The present findings bear on the question of the nature of feedback and correction procedures. These results tentatively suggest that less elaborate and straightforward feedback and correction procedures are as effective as the more elaborate prompting, response-contingent feedback, and overt correction procedures. These conclusions will be checked with other subject matters and other students to establish their degree of generality.

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Some Comments on the Efficiency of the Typewriter Interface in Computer-Assisted Instruction at the High School and College Levels

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A Brief Description of the Penn State CAI System

For the past two years, faculty members at Penn State have been preparing courses for presentation to students via an IBM 7010 computer system. The courses involved are modern mathematics, cost accounting, audiology, and engineering economics, at the college level; and technical physics, mathematics, and communications skills at the two-year post-high school vocational training level. Courses are being prepared by means of a programming language known as Coursewriter developed by IBM computer scientists at the Thomas J. Watson Research Center, Yorktown Heights, New York. The Coursewriter language enables an instructor, with a minimum of special training, to develop a CAI course including questions, problems, assignments, correct answers, incorrect answers, provisions for unanticipated answers, knowledge of results, and branches or alterations in the instructional sequence. By means of additional special codes, the instructor can program the computer to present slides or tape recorded material at the student's terminal, and can request partial answer processing of student answers. This latter operation permits a student to give answers several words in length and instructs the computer to ignore trivial characters such as commas, periods, spaces, differences in word order, and misspelling if desired. The computer automatically records and stores all student responses, errors, and response times. The instructor can later obtain a print-out and statistical analysis of these data by means of a special procedure known as Student Records.

Course material is stored on a magnetic disc to which the computer has selective access to any part with an access time of less than one second. The course is presented to students via an IBM 1050 communications system which includes a modified IBM electric typewriter, a random access slide projector, and a tape recorder. Information, questions, or problems can be presented to the student either through typewriter type-out, slides, or tape recordings. In responding to a question or problem, the student simply types his answer on the typewriter and relays it to the central computer by pressing a button. The computer than evaluates the response by comparing it with pre-stored criteria for correct answers, and provides immediate knowledge of results to the student. The student terminals are located on the Penn State campus. Two main computers are in current use, one located on the Penn State campus and the other at Yorktown Heights, New York. Transmission of information between the student and the computer takes place over voice-grade telephone lines by means of teleprocessing.

The major objectives of the Penn State CAI Laboratory may be briefly summarized as follows:

1) The development of prototype CAI course materials at the college and technical education levels.
2) Test the feasibility of CAI at the college and two-year post-high school technical education level, and the feasibility of CAI via remote teleprocessing. Determine the nature and extent of any special educational problems which may result from CAI.
3) Conduct research on problems related to individualized instruction via CAI and to implement our findings by developing instructional programs which adapt to individual differences among learners.

Today, I would like to confine my remarks to some preliminary results and experiences we have had with the typewriter interface in the hope that our experience might be of some value to new prospective CAI users. In doing this I risk giving you an overly narrow view of the interests of our Laboratory. For those of you who may be interested in other phases of our work, descriptions of our courses, etc., I have brought copies of a more general paper and several copies of our last semi-annual report.

<u>Some comments on the typewriter interface</u>

Glaser, Ramage, and Lipson (1964) have prepared an excellent discussion of the interface problem in computer-assisted instruction. For those of you not familiar with the CAI terminology currently in vogue, the term interface refers to the input and output devices through which the subject matter is presented to the learner and through which the learner makes his response. The interface might include auditory communication devices, visual communication devices varying in sophistication from simple slide projectors to cathode ray tube displays, two-way typewriters of the type currently in use at Penn State, etc. In general, Glaser, Ramage, and Lipson urge maximum flexibility in the interface so that a wide variety of instructional strategies may be implemented, a point of view shared by the present writers.

In discussions of the interface between student and subject matter in CAI, the typewriter usually draws a substantial amount of time. Some of the disadvantages which have been attributed to the typewriter interface are "penalizes the nontypist," "inappropriate for use with young children," "too slow in transmitting information to the student," etc. Some of the advantages ascribed to the typewriter interface have been "provides for constructed response," "permits remote teleprocessing," "provides hard-copy for the student," and so on. Some of our preliminary research raises some questions concerning the efficiency of the typewriter interface.

Several studies are presently being conducted on various problems related to individualized instruction. Although this research is still in progress, two of the studies provide preliminary data on the efficiency of the typewriter as a communication device for high school and college level instruction. Table 4.3 presents part of the data of one study which compared equivalent instructional materials presented "on-line"[2] and "off-line" in the form of a programed text. This comparison is shown in rows A and B of Table 4.3. Row C of Table 4.3 contains a condition we call a "linear coursewriter" program administered "on-line." This program differs from A and B in that each frame contains several prompts and cues designed to elicit a correct response from a student who initially makes an error. Condition D, a branching coursewriter program, was included in Table 4.3 to indicate the direction of our future research. Through condition D we eventually hope to produce a program which adjusts instruction to relevant individual differences among learners to produce maximum achievement in a minimum amount of instructional time. The

[2] "On-line" in the present context means that all instruction was taken via CAI at the typewriter interface. "Off-line" means that the course was taken in the form of a programed text.

Table 4.3

Comparison of Mean Posttest, Retention Test, and Instructional Time for On-line and Off-line Instruction in Technical Physics (High School Student Sample)

	Pre-test	Posttest	6-week retention	Instructional Time (minutes)
(A) Linear Programed text (off-line) (n = 22)	1.06	20.6	17.0	42
(B) Linear Programed text (on-line) (n = 22)	1.09	20.0	15.3	52
(C) Linear Coursewriter Program (on-line) (n = 22)	0.91	21.9	17.9	68
(D) Branching Coursewriter Program (on-line)				
	n.s.	n.s.	n.s.	$P < .001$

subjects in the study were high school students. The instructional program was relatively "nonverbal," consisting primarily of short questions and verbal communications.

Table 4.3 shows that although the posttest and retention scores were nonsignificantly different for the three groups, that the variations in instructional time were highly significant. The time lost by administering the same material via the typewriter interface was 10 minutes. (If two extreme subjects are eliminated from the "off-line" group the mean time drops to 35 minutes.) Comparing conditions B and C indicates that we lose another 17 minutes by adding prompts and by requiring the student to produce the correct response by typing it into the machine.

Similar data from another study using a small sample of college students and a program with longer typed questions and messages obtained a mean time "off-line" of 51 minutes (n = 8) and a mean time "on-line" of 80 minutes (n = 7). Several of the students in the "on-line" group took a short five-item pretest and five-item post-test which is included in their time, however; an adjustment for this additional activity still leaves a rather substantial time difference.

These time differences can be reduced to some extent by programming to eliminate a number of typewriter carriage returns which are currently built into our programs (each taking approximately 1.3 seconds). The time differences may also be reduced after students have had more experience working with the typewriter terminal and are able to operate it more rapidly. However, some portion of the time loss is undoubtedly due to the large difference between the typeout rate of the typewriter (approximately 120 words per minute) and the reading speed of the typical high school or college student. The average highly verbal student appears capable of assimilating information at a rate considerably faster than can be communicated to him through the typewriter interface. Obviously the instructional time lost will be greater for subject matter which is highly verbal in nature, and for highly verbal students. It is impossible to estimate the exact extent of the time loss for different subject matters at the present time. Admittedly, our data require replication with larger samples of students and different subject matters. However, in an area of research where instructional manipulations generally produce only small gains in student achievement, a time loss of the order of 25 per cent represents a substantial amount. Students could be given 25 per cent additional practice, instruction on new material, practice on transfer problems, etc. In addition to the gains in student learning which might result from a more efficient use of instructional time, there are also economic considerations in the cost of computer time, tie-lines, and other "hidden" costs involved in the preparation of the courses. All other things being equal, by employing an interface which would increase the amount learned per unit of time by say 25 per cent, four students could be taught for every three taught by means of a typewriter.

It is also important to realize that from the college student's point of view, learning at a typewriter terminal is not self-paced instruction since he must slow down his normal rate of work. Pacing instruction below a student's optimal rate could produce boredom, negativism, and avoidance of CAI as an aid to learning. This is not an uncommon finding when the pace of classroom instruction by the lecture method is [illegible] slow for the brighter students.

What are the possibilities for speeding up instruction using a typewriter interface? We have considered the possibility of putting all lengthy, typed communications, and possibly all stimulus materials on slides for more rapid presentation to students. Two factors weigh against this proposal: a) The slide production and duplication problem becomes immense for any full length course used with a number of students simultaneously; b) The presentation of questions, problems, and other messages via the slide projector leaves the student with no hard-copy as a record of his work. It would be much simpler to put all course materials in a display book and use the typewriter solely to direct the student to a particular question, problem, or display, and as a response input device. Following this strategy, the CAI system would not be used to display instructional material, but to evaluate student responses and to refer the student to appropriate display materials according to his progress in the course.

Another question which is frequently raised concerning the typewriter interface is the extent to which typing ability affects student performance. In the first study described above, students were identified as typists or nontypists on the basis of interview data. A comparison of the posttest achievement and retention scores of typists and nontypists showed no statistically significant differences. This finding is not surprising since the responses required in most of our programs are relatively short one-word or at most two-word responses. However, as might be expected, typing ability does appear to relate to the time variable particularly when the program requires much interaction between the student and the subject matter through the typewriter interface. Table 4.4 shows the mean times for typists and nontypists in programs B and C. Program B was the linear program which required only one response per frame; program C was the course which was programed to anticipate student errors, and to elicit a correct response by means of successive prompts. The time difference for typists and nontypists was 2 minutes on the average for program B, and 12 minutes on the average for program C.

Table 4.4

Typing Ability and Instructional Time (in minutes) at the Typewriter Interface

	Program B	Program C
Typist	n = 14 Mean Time = 51	n = 10 Mean Time = 64
Nontypist	n = 8 Mean Time = 53	n = 12 Mean Time = 76

Tentative Conclusions

a) On the basis of preliminary evidence the two-way typewriter does not appear to be the most efficient interface for transmission of highly verbal information to highly verbal learners. The typewriter interface transmits information at a rate considerably slower than the reading rate of typical high school or college students.

b) The typewriter interface would seem to be more appropriate for relatively nonverbal content areas and for students who normally work at a fairly slow pace.

c) The typewriter in CAI might be used more efficiently as a response entry device rather than as a device for communicating the subject matter.

d) The typewriter interface has the advantage of remote teleprocessing and makes available a printout of the instruction for the student.

e) Perhaps the optimal interface for highly verbal material, and highly verbal learners will be a rapid visual display device such as the cathode ray tube, with remote teleprocessing capability, and the ability to store, and later print out at the request of the student, a record of his exercises and actual responses.

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Supplementary Data on Deficits in Instructional Time Resulting from The Typewriter Interface

Kenneth H. Wodtke, David A. Gilman, and Tracy Logan

The previous paper reports the extent to which the use of a typewriter as a communication device in computer-assisted instruction (CAI) slows down the pace of instruction when compared to self-paced instruction via programed text. In view of the importance of this question, the previous results were replicated on a new sample of students.

Two identical instructional programs on significant figures were compared. One version of the program was prepared for administration to students by the CAI typewriter communication device; the other for presentation by programed text. The students were pretested and posttested on the ability to identify the correct number of significant figures in a numerical answer. In addition, the instructional time was recorded for each student. The results are shown in Table 4.5. Although the pretest and posttest means did not differ for the "on-line" and "off-line" groups, the group receiving instruction via the typewriter took 33 minutes longer on the average than the programed text group. This represents a percentage increase in instructional time of 75 per cent attributable to the slow rate of typewriter communication without any compensating increase in achievement for this group. It should be noted that the present instructional program was one in which a large number of students reached mastery of the concepts. In a posttest designed to measure transfer to problems not specifically taught in the program, 70 per cent of the students in the programed text group achieved perfect scores. Only two out of 26 students in this group made more than one error on the transfer posttest.

For a discussion and implications of these findings, the reader is referred to the earlier paper contained in this report entitled "Some Comments on the Efficiency of the Typewriter Interface in Computer-Assisted Instruction," by Kenneth H. Wodtke and David A. Gilman.

Table 4.5

Supplementary Data on Time Deficits Resulting from the Typewriter Interface

Experimental Group	N	Mean Pretest	Mean Posttest	Mean Instructional Time (minutes)
CAI ("on-line")	9	.9	8.5	77
Programed Text ("off-line")	27	.7	9.9	44

The Effects of Rote Rule-learning on Transfer of Training[1]

Tracy H. Logan and Kenneth H. Wodtke

Many subject matters abound with rules which may be used by students in solving problems. The utility of a rule will depend upon its generality to many problem situations. A rule with high utility will be applicable in many problems and have only a few exceptions. A lower utility rule will be applicable to fewer situations and will have many more exceptions. Quantitative subjects such as mathematics, statistics, measurement, and the sciences typically employ a large number of such rules varying in terms of their applicability to a wide variety of problems. The application of rules in problem solving may have a great deal of utility for students. Indeed, the fact that rules are frequently included in instruction in mathematics and science is testimony to their utility.

In spite of the great utility of rules in problem solving, most instructors would agree that teaching students to solve problems by a set of rules is not sufficient. Although the rules may provide an immediate parsimony in achieving solutions to problems, rules applied in "cook book" fashion do not provide the basic understanding of the processes involved in the solution. For example, students taught to solve statistical problems by means of the rote application of formulas would not be expected to perform well in a transfer situation which required understanding of a higher order principle. Instruction which provided the basic understanding of the principles underlying the rules, and an understanding of why the rules worked in some problems and not others, should facilitate transfer to problems in which a rule did not apply.

In teaching the use of rules in problem solving, an instructor must be especially careful to teach the student when the use of the rule is appropriate. A common consequence of rote-rule learning is the student's failure to recognize the exceptions to the rule. Rules may be blindly and inappropriately applied, particularly when the students

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[1] This report is a summary of some of the major findings of the first author's doctoral research, a portion of which he completed while a Science Faculty Fellow of the National Science Foundation.

have not been taught to discriminate between the situations in which the rule is appropriate and the situations in which it is inappropriate. The teacher's admonitions to "remember the exceptions to the rule" frequently fall on deaf ears.

The present study sought to accomplish two major objectives:

(1) By means of an experimental paradigm which simulated a common classroom teaching sequence, the study attempted to demonstrate the detrimental effects of adding rote rules-of-thumb to instruction designed to facilitate basic understanding and transfer of training.

(2) The study also compared the effects on transfer of two rule practice sequences, one in which the rule was given after instruction but before a practice segment, and another in which the rule was given following both instruction and practice. (See Table 4.6 for the sequence of experimental events.)

Table 4.6

Experimental Sequences

Condition I (No-rules)	Condition II (Rules-early)	Condition III (Rules-late)
Pretest	Pretest	Pretest
Basic Instruction: Significant Figures in Multiplication	Basic Instruction: Significant Figures in Multiplication	Basic Instruction: Significant Figures in Multiplication
Practice Problems	Rule given for multiplication	Practice Problems
Transfer Posttest: Addition and Trigonometry	Practice Problems	Rule given for multiplication
	Transfer Posttest: Addition and Trigonometry	Transfer Posttest: Addition and Trigonometry

This comparison was designed to test the hypothesis that the addition of a rote rule-of-thumb to an instructional program which strives for understanding will, if it comes before the student is given a chance to use his basic understanding in practice problems, produce a decrement in performance on transfer tasks.

The effects of rote rules of thumb on transfer of training.

The first phase of the investigation was stimulated by the writer's observations of actual classroom teaching situations. A typical lecture presentation in college mathematics, statistics, or science, frequently follows the following sequence: The instructor spends the first part of the hour attempting to produce basic understanding of the concepts covered. Following the basic instruction the last few minutes of the hour may be devoted to a "summing up." During this period the students may often be given the formulas and rules for applying the formulas in solving problems, with the usual perfunctory warnings by the instructor to "Remember, the rule only applies in situation A," or "These rules are helpful, but you should really rely upon your basic understanding," etc. In actual practice, such admonitions seem to have very little effect on student behavior, and serve only to dispel the instructor's fears that the rules might be misapplied. In the experience of the writers, students frequently fail to heed the warnings of the instructor, and apply the rule in transfer situations in which the rule is inappropriate and produces incorrect responses. These incorrect responses occur in spite of the fact that the student could draw on the basic understandings taught previously to correctly solve the problem. Thus, the tendency to use a rote rule even though the rule does not apply seems to hold a dominant position among the student's strategies of problem solving. The strategy which involves the blind application of a rule is preferred by the student to a strategy which involves thinking through the problem and using his understanding. Phase one of this investigation consisted of an attempt to simulate such an instructional sequence to demonstrate the extent of the damage which can be done by teaching students to use rules in a superficial manner.

The topic of instruction chosen for the investigation was significant figures at the level of introductory quantitative high school or college physics. The concept of significant figures was chosen because teachers and textbooks typically use a well-known rule[2] in teaching the concept; however, the rule does not apply to all problems involving the determination of the number of significant figures in a numerical calculation.

The instruction was presented in the form of a programed text designed to produce basic understanding of the reasons why only a certain number of significant digits are retained in the product of multiplying two numbers. The basic instructional program contained no rules-of-thumb for arriving at the correct number of significant figures in an answer, and all instruction was conducted in the context of multiplication problems. A short practice segment followed instruction, in each of the experimental conditions.

College students in introductory educational psychology were pretested to determine their ability to obtain the correct number of significant figures in computational problems. Seventy-nine students were selected who exhibited minimal knowledge of significant figures on the pretest. These students were then assigned at random to one of three experimental conditions. Condition I, hereafter referred to as the "no-rules" condition, consisted of the pretest, basic instruction in significant figures using the programed text, and a short series of practice problems followed by several transfer posttests measuring the ability to determine the correct number of significant figures in problems not specifically taught in the program. The problems to be solved in the transfer posttests consisted of addition and trigonometry and could not be solved correctly by the application of the multiplication rule taught in the two "rules" conditions. Condition II consisted of the same basic instruction as Condition I, except that a simple rule-of-thumb which was applicable only to multiplication problems was included prior to the practice problems. The same transfer tasks consisting of addition and trigonometry problems were administered following instruction in Condition II. Condition II is hereafter referred to as the "rules-early" condition. Finally Condition III consisted of the same sequence as Condition II except that the rule-of-thumb for solving multiplication problems was given

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[2]Rule: When multiplying or dividing, the result has just as many significant figures as the factor with the fewest significant figures.

following the practice problems. Condition III will be referred to as the "rules-late" condition. The three groups were compared to determine what effect giving the students the multiplication rule would have on their transfer to problems in addition and trigonometry.

Lest the reader think that the students were "tricked" into believing that the rule would work in all problems, he should note that emphatic warnings were placed at three different points in the program for the two rule groups. Upon introducing the multiplication rule the student was told, "It is just a rule-of-thumb, and works only for products and quotients, not for sums." In effect, the students were told that the rule would not apply in the transfer task involving addition problems. At the end of the rule section the students were told,

> "...as with many rules, there are occasional exceptions where the rule gives an incorrect answer. Therefore you are strongly advised to check ANY rule-result by using the basic reasoning of significant figures until you get a feeling for when the rule works and when it doesn't---say, at least for the next week or so."

Preceding the addition section of the posttest the students were told, "Although you have not practiced these, you can reason them out. Just trust your brain."

Table 4.6 shows the experimental design and the sequence of events in the three experimental conditions. As is indicated in the table, all three experimental groups were given basic instruction in multiplication designed to produce transfer to addition and trigonometry problems. The only differences between the groups were the presence of the rule for multiplication, the admonitions to use the rule only when appropriate, and the rule-practice sequence.

The Kuder-Richardson formula 20 reliability of the eight-item transfer posttest including both addition and trigonometry problems was found to be .7.

The mean performance of the three experimental groups on the transfer problems is shown in Table 4.7. Mann-Whitney U-tests (Siegel, 1956) were computed to compare the performance in the three treatment conditions. Mann-Whitney U-tests were used because the distributions of scores within the three experimental groups were highly skewed. The results indicate that both rules conditions significantly depressed transfer

Table 4.7

Mean Performance of the Three Experimental Groups on the Transfer Tasks

Experimental Condition	N	Addition Test (5 problems)	Trigonometry Test (3 problems)	Total Transfer Test (8 problems)
No-rule	26	4.5	1.6	6.1
Rule-early	26	3.5	1.2	4.7
Rule-late	27	2.6	1.0	3.6

Mann-Whitney U-tests:

	Addition	Trigonometry	Total
No-rules vs. Rules early	.02	.07	.02
No-rules vs. Rules late	<.0001	<.01	<.0001
Rules early vs. Rules late	.03	n.s.	.05

Table 4.8

Mean Performance of the Three Experimental Groups on the Transfer Tasks for Those Students Who Exhibited Low Pretest Performance Immediately Prior to Instruction

Experimental Condition	N	Addition (5 problems)	Total (8 problems)
No-rule	12	4.7	6.2
Rule-early	10	2.6	3.8
Rule-late	10	2.2	3.2

Mann-Whitney U-tests:

	Addition	Total
No-rules vs. Rules Early	<.01	<.01
No-rules vs. Rules late	<.01	<.01
Rules early vs. Rules late	n.s.	n.s.

to the addition, trigonometry, and total transfer tasks. The probability values for the comparisons of the no-rules group with both of the rules conditions ranged from 0.07 to less than .0001. Eighteen of the 26 students in the no-rules group achieved perfect scores of 5 on the addition transfer problems, whereas only 20 of 53 students in the two rules-groups achieved perfect scores.

Many of the students in the sample reported having had some instruction on significant figures although their poor performance on the initial pretest would have suggested the contrary conclusion. In view of these student reports the authors suspected that a good many students might have had familiarity with the concept of significant figures in spite of their inability to produce correct responses on the pretest. Furthermore, since the pretest was administered approximately five days prior to the experimental training we were concerned that the pretest might sensitize these students to their previous training in significant figures. Although one would expect such effects to be distributed at random through the three experimental groups, an attempt was made to eliminate this possible source of experimental error from the analyses. Approximately one-half of the students were given a second pretest immediately preceding the experimental sessions. Thirteen of forty-five students actually exhibited improved performance on the second pretest prior to receiving the instructional program. These thirteen students were eliminated from the sample, and a second analysis was performed on the remaining naive students only. The mean transfer test performance for these students in the three experimental conditions is shown in Table 4.8. The Mann-Whitney U-tests were consistent with the first analysis. The data indicate that for the addition and total transfer tasks, both rules conditions produced a significant decrement in performance from that obtained in the no-rules condition.

By examining the errors made by students on the transfer problems it was possible to determine the number of errors which may be ascribed to a misapplication of the rule for multiplication. Table 4.9 shows the mean number of addition problems answered correctly by the three experimental groups, the mean number of rule misuses (i.e., use of the multiplication rule in an addition problem), and a corrected score consisting of the mean number of correct responses plus the mean number of rule misuses. These data suggest that the decrements in performance of the rules groups on the transfer task resulted from the

Table 4.9

Mean Frequency of Rule Misuse in the Three Experimental Groups

Experimental Condition	N	Addition Posttest (5 items)	Rule Misuses	Corrected Score (Addition & Misuses)
No-rule	26	4.5	0.1	4.6
Rule early	26	3.5	1.0	4.5
Rule late	27	2.6	1.9	4.5

students' tendency to use the rule in problems where it did not apply. These results seem to indicate quite clearly that the verbal warnings to the students that the rule was not appropriate for obtaining sums, and the encouragement to "just trust your brain" had relatively little effect on student behavior. Students in the groups given the rule-of-thumb went right on applying the rule to problems even though they were told the rule did not apply.

Although the effect of rule misuse was generally evident in both of the rules groups, students in the rule-late group were far more consistent in their misuse of the rule than the students in the rule-early group. We are not certain as to what interpretation to place on this finding at the present time. Several explanations are being considered for verification in future research.

The effects of rule-practice sequence on transfer

This phase of the investigation examined the hypothesis that a condition in which a rule was given before practice would have a more detrimental effect on transfer than a condition in which the rule was given after practice. This hypothesis was based on the supposition that students would, if given the rule before the practice problems, practice using the rule, and would not exercise the problem-solving strategies developed in the basic instruction. On the other hand, students who did not have the rule available until after the practice session would be forced to solve the practice problems using the understanding of significant figures which was developed by the basic program. This hypothesis was not confirmed. Of the five comparisons of the rule-early versus rule-late groups on the transfer tasks shown in Tables 4.7,-8, three are clearly nonsignificant, one is significant at the 5 per cent level, and one is significant at less than the 3 per cent level. In every case, however, the differences between the groups are in the direction opposite to that which was predicted. This difference appears to have resulted from a chance effect due to the pretest sensitization effect. When the results for naive students only are analyzed as shown in Table 4.8 the mean transfer scores for the rule-early and rule-late groups are nearly identical.

Conclusions

(1) The presence of a rote rule-of-thumb in an instructional sequence designed to facilitate transfer to problems which were not specifically taught in the program, and to which the rule did not apply, produced a marked decrement in performance on the transfer tasks. The decrement on the transfer tasks was obtained by comparing an instructional program containing a rote rule-of-thumb with an identical program containing no such rules. The transfer decrement occurred in spite of the fact that the students were given a didactic warning indicating that the rule would not apply on the transfer problems. The results of the study indicate that didactic verbal warnings to students have little effect on their behavior in an actual transfer situation. The writers believe that the results of the present study are fairly typical of actual classroom teaching practice, and that much more care should be taken in preparing instruction which involves the use of rules-of-thumb in problem solving.

(2) The present results indicate that it makes little difference whether the rule-of-thumb precedes practice or follows practice. In either case the presence of the rule inhibits performance on transfer tasks when compared to a group taught without the use of rules. For example, if one examines the percentage of naive students in each experimental group which reached "mastery" on the addition transfer tasks, mastery being defined as perfect performance, one finds that only 20% of the rule-late groups, 20% of the rule-early group, but 75% of the no-rules group reached mastery!

(3) A supplementary examination of the responses made by the students in the transfer

tasks indicated that the poor performance of the rule-groups resulted to a considerable extent from their misuse or overgeneralization of the rule. The misuse of the rule occurred even though students had been warned several times concerning the inapplicability of the rule to the transfer situation.

The writers do not take the present results to indicate that computational rules or algorithms should not be included in quantitative instruction, but only that teaching students to use such rules appropriately requires special instructional procedures which are frequently omitted in actual practice. The apparent tendency of students to overlearn a simple rule-of-thumb at the expense of their basic understanding of the processes involved would seem to indicate that much more care should be taken in the preparation of instructional materials designed to produce basic understanding and transfer of training. The results of the present study are probably most easily interpreted as a case of the students' failure to discriminate problems in which the rule applies from problems in which the rules does not apply. Perhaps the optimal instructional program would provide the basic understanding, useful problem solving rules, and the discrimination training needed to help the student avoid instances of rule misuse. Most instructional situations do not provide the discrimination training necessary to reduce the frequency of rule misuse. It is quite evident in the present results that this objective is not achieved by simple didactic verbal statements. As a general recommendation for teachers in quantitative subjects, if simple rules-of-thumb are to be taught, much discrimination training in the use of the rules will probably be necessary in order to avoid the students' tendencies to blindly apply the rules without regard to the appropriateness of the situation.

Although one might presumably argue that the present results indicate that rules-of-thumb should be avoided in quantitative instruction altogether, there are obviously many problem solving situations in which such rules have great utility. Ideally, a student should be able to capitalize on the increased efficiency provided by the rules in problem solving, but he should also be able to select the appropriate rule for a particular problem, and be able to rely upon his basic understanding of the processes involved when he recognizes that no existing rule applies.

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CHAPTER V

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