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ABSTRACT

Two beginning reading curricula that use computer assisted instruction were developed during 12 years of work at Stanford University. This paper describes those curricula and the motivations, assumptions, procedures, and problems that were involved in their construction. Twelve observations about curricular design and development are summarized to help others interested in the developing field of cost-effective, individualized instruction. (Discussion following presentation of the paper is included.) (RL)

Computer Assisted Instruction in Beginning Reading: The Stanford Projects

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Computer Assisted Instruction in Beginning Reading: The Stanford Projects

Introduction

Design and development of computer-assisted instruction (CAI) in beginning reading were undertaken by Richard C. Atkinson and his staff over a twelve-year period, 1964-1975, at the Institute for Mathematical Studies in the Social Sciences at Stanford University. Two beginning reading CAI curriculums were developed during this period, one designed for the IBM 1500 Instructional System and the other designed for the Institute's Digital Equipment Corporation PDP-10 computer facility.

Development for the 1500 curriculum began in 1964 and ended in the spring of 1968. The system was used for two school years; about 50 first-grade students used the reading curriculum in 1966-67 and about 70 students in grades K-2 used the reading curriculum in 1967-68. The 1500 system supported elaborate student terminals including three display, or output, devices — a picture projector, a cathode ray tube (CRT), and an audio system for playing prerecorded messages. The terminals also included three student input devices — a hand-held light pen, a modified typewriter keyboard, and (again) the audio system for recording messages. The picture projector provided random access to 1024 16-millimeter film frames that were displayed on a 7-by 9-inch screen. The CRT displayed alphanumeric characters on

a 7-by 9-inch screen with 16 lines of 40 character positions each. A limited number of prepared line drawings could also be displayed on the CRT. The audio system provided random access to messages that could vary in duration from 1 to 15 seconds and were stored on a tape cartridge containing about 2 hours of prerecorded messages. The light pen was the principal input device used by the reading program. It was activated by being pressed against one of the CRT character positions which was then sensed as a response and recorded. The typewriter keyboard was used occasionally by the reading program in a straightforward way. The record capability of the audio system was seldom used. Early studies indicated that students preferred to use this capability for recording messages of their own devising that incorporated a vocabulary more distinguished by its colorfulness than by its utility in reading pedagogy. The computer system and its terminals were located at an elementary school in a predominately Black, economically depressed neighborhood. More complete descriptions of this system were provided by Atkinson and Hansen (1966) and Atkinson (1968).

Development of the PDP-10 curriculum began in 1968 and ended in the spring of 1975. The computer system was located at Stanford University and communicated with student terminals in participating schools over dedicated telephone lines. The system was used for six school years, beginning with the same school used for the 1500 development and about 200 first-grade students in 1969-70, expanding to four schools and about 700 students in grades K-3 in 1970-72, and cutting back because of funding limitations to the original school in 1972-75 with about 400 students each year primarily in grades K-3,

although some students in grades two also participated as remedial readers. The PDP-10 system supported relatively simple student terminals consisting of 10-character a second, KSR "Model 33" teletypewriters equipped with headphones for digitized audio output. The teletypewriter provided hard-copy displays and the principal means for student input. Students received prerecorded messages from the digitized audio capability which permitted prerecording on magnetic disk of up to 6000 digitized messages one-half, one, or two and a half seconds in length. The messages could then be rapidly ([illegible] milliseconds) accessed at random, assembled together in computer memory, and, after digital to analogue conversion, played to a student through his headphones. There was no graphic or photographic capability at the terminals, and the teletypewriter printed only upper-case letters. This system was described more completely by Atkinson and Fletcher (1972), Atkinson, Fletcher, Lindsay, Campbell, and Barr (1973), and Atkinson (1974).

There were three primary motivations for the Stanford projects in beginning reading. First, they were motivated by their obvious potential for investigating hypotheses, or notions, proposed to account for the acquisition and retention of reading skills. A variety of studies completed in the context of the Stanford beginning reading curriculum serve to illustrate the feasibility of CAI used to investigate basic hypotheses concerning reading pedogogy.

Second, the projects were motivated by their potential for demonstrating the feasibility of CAI as a medium for instruction in

the primary grades. The technical, economic, and administrative feasibilities of CAI were discussed by Atkinson (1968, 1974), Fletcher and Atkinson (1972), and Jamison, Fletcher, Suppes, and Atkinson (in press). There seems little reason to doubt the technical and administrative feasibility of CAI; effective instruction was delivered and used by primary grade students. A case can also be made for the economic feasibility of large scale implementation of the CAI delivered by the Stanford projects using computer processing and storage cost data from the late 1960's. The recent, dramatic decreases in the costs of computation make possible the economic feasibility of beginning reading CAI on a much smaller scale than that suggested by Jamison et al.

Third, the projects were motivated by their potential for developing instructional strategies and techniques for CAI itself. In the 1960's there were numerous data-free polemics on the most efficacious use of CAI. The Stanford projects were major efforts to curtail these polemics with "real-world" data on the educationally powerful issues of beginning reading. A variety of developments such as the strands techniques (e.g. Suppes, 1967), optimized instruction (e.g., Atkinson, 1972), and digitized audio applications had their genesis in the early commitments of CAI to operational environments.

The remainder of this paper consists of four sections. The first documents some of the relevant assumptions on which the design of the curriculums were based. The second discusses the design of the 1500-system reading curriculum. The third discusses ~~the design of the PDP-10,~~ or teletypewriter, reading curriculum. The fourth section presents

some final comments on the Stanford reading projects.

Assumptions

Few activities demand as much precision and accuracy in theories as the translation of their precepts to computer programs. In the case of the Stanford reading curriculums, help was simply taken from wherever it was available, and linguistic notions provided the richest background for curriculum development. In many instances, of course, there was nothing to be done but rely on the intuitions of the project staff, consultants, and participating school personnel. This mix of linguistic, psycholinguistic, pedagogic, and intuitive considerations yielded the assumptions underlying the initial reading curriculums.

In the Stanford curriculums the reading process was viewed as a translation of printed orthography to meaning in a manner paralleling that of speech perception in which the translation is from an acoustic signal to meaning, necessitating some form of analysis-by-synthesis on the part of the perceiver. It was assumed that there is a level of abstraction below meaning that is common to both speech perception and reading and that this level is adjusted upward or downward depending on the ease or difficulty of the material being read.

This view of reading engendered another idea that had a lasting effect on the CAI reading curriculums. As expressed by Carrol (1964), reading can be analyzed into two processes: the construction or reconstruction of a spoken message, and the comprehension of messages so constructed. Taking this cue from Carroll, the emphasis in both the CAI reading curriculums was on speech reconstruction, that being

the activity more amenable to computer presentation. Carroll went on to recommend that "these two processes -- speech reconstruction and the apprehension of meaning -- should [not] be separated in procedures of teaching. There is evidence, if fact, that the teaching of the mechanics of speech reconstruction (techniques of word recognition) is best done with materials which are maximally meaningful to the learner" (p. 336). To a minor extent, this latter recommendation was not followed in designing both curriculums. The 1500-system curriculum taught nonsense, but 'regularly pronounceable', monosyllables, and the PDP-10 curriculum taught meaning-free spelling patterns. Additionally, of course, both curriculums taught words; the 1500-system curriculum presented only regular words and the PDP-10 curriculum, with its more pragmatic orientation, taught regular and irregular words.

It should be noted that amenability of pedagogical notions to computer presentation was a factor in the design of these curriculums. A primary difficulty in CAI design is the translation of instructional prescriptions to computer programs. There appear to be two basic reasons for this difficulty. First, most instructional prescriptions are vague relative to the precision required by computer programming. In one sense, CAI represents the reductio ad absurdum for a behavioral objectives approach to instructional design. It is difficult to incorporate in CAI objectives that cannot be expressed as behaviors measurable at a computer terminal.

Second, despite all its capabilities and promise, the state of the art in computer technology has manifest limitations for instruction. These limitations are particularly noticeable for instruction in

natural language skills. Currently there are genuine capabilities for speech understanding by computers and for comprehension of text, but it is doubtful that these capabilities are sufficiently powerful for CAI in beginning reading.

Both of the CAI curriculums were designed to supplement whatever reading instruction occurred in the classroom. It was assumed to be far easier to adjust and modify the computer programs used for instruction than to adjust and modify the established practice of classroom teachers. The supplemental nature of the Stanford curriculums with its requirement for activities that could complement any classroom reading instruction combined with the requirement for relatively precise instructional prescriptions to effect a major emphasis in both curriculum on decoding — the ability to synthesize, or 'sound out', an acoustic signal from orthography.

It was assumed that the linguistic skills of 5-7 year old children could be enlisted in teaching them to read if they could just be taught to relate written symbology to the productive language capabilities they already possessed and demonstrated in their spoken language. Moreover, there seemed little reason to teach children solely to associate specific words with specific acoustic representations when a transfer capability appeared to be promised by the structure of English orthography. Orthography is a shared code based on competencies common to large communities of users, and it seemed intuitively plausible that such a sharing implies rules for associating writing with speaking. If students could be placed in situations where they would learn these rules, they might learn to break the code. Once the code was broken,

the syntactic and semantic information associated with the acoustic information they could now synthesize from text might follow automatically. The situations appropriate for breaking this code appeared to be those in which the orthographic information bore a 'regular' relationship to the acoustic information it was intended to represent -- in which there would be 'regular grapheme-phoneme correspondences.'

In the practice of the 1960's the 'graph' or grapheme could be a single letter, a syllable, or a word. In the Bloomfield and Barnhart (1961), Lippincott (McCracken and Walcutt, 1963), Merrill (Fries, Wilson, & Rudolph, 1966), and Behavioral Research Laboratories (Sullivan, 1967) readers, the initial grapheme-phoneme correspondences were VC (vowel-consonant) syllables presented in words that were generally of a CVC configuration. VC words were also allowed early in these readers and Lippincott permitted double consonant clusters (CCVC, CVCC, and CCVCC) as well as CV words. Evidently, these readers assumed that the basic graphic unit in beginning reading should be larger than a single letter and smaller than a whole word. Use of these units seems reasonable because of the difficulty of pronouncing consonants separate from vowels. In conventional practice, this difficulty is resolved by associating consonants with some 'neutral' vowel such as /ə/. However, it should be noted that, for instance, as useful as an association between the grapheme B and the phoneme /bə/ may be in pronouncing BUT, it may be useless or even confusing in pronouncing BIT. Neither of the Stanford reading curriculums taught associations between single letters and the sounds they represented.

This approach was supported by Fries (1963) who emphasized that

the approach to beginning reading recommended by Bloomfield and himself rests:

> Upon the relation between the sound patterns of the words and the letter symbols of an alphabet but this relation is not such as to lead us to seek to match specific letters with each of the physical 'sounds' of our language. Nor does it assume that the pronunciation of a word is a fusion or blending of the sounds represented by the individual letters by which the word is spelled (p. 146).

Fries' position is that: "modern English spelling is fundamentally a system of a comparatively few arbitrary contrastive sets of spelling-patterns to which readers, to be efficient must, through much practice, develop high-speed recognition responses" (p. 146). Fries' statements concerning the development of high speed recognition responses antedate recent pronouncements to the same effect by LaBerge and Samuels (1974) who based their comments on considerable empirical study.

Coming from psychology rather than linguistics, Eleanor Gibson (1970) stated that:

> It is my belief that the smallest component units in written English are spelling patterns. By spelling patterns, I mean a cluster of graphemes in a given environment which has an invariant pronunciation according to the rules of English. These rules are the regularities which appear, when for instance, any vowel or consonant or cluster is shown to correspond with a given pronuncia-

tion in an initial, medial, or final position in the spelling of a word (p. 329).

Spelling patterns as described by Gibson were used heavily in the Stanford PLI-10 curriculum which incorporated substantial amounts of practice in an attempt to bring about the high-speed recognition responses recommended by Fries. The utility of this approach in CAI was demonstrated by Fletcher and Atkinson (1972) and Fletcher (1973). However, emphasis on phoneme-grapheme regularity encounters practical difficulties in curriculum design for beginning reading. One obvious difficulty is the strained vocabulary that results in choosing words to illustrate the regular spelling patterns being presented, and another is the pronunciation of orthographically regular utterances in ordinary discourse. Both of these difficulties are illustrated by Bloomfield's prototypal NAN CAN FAN DAN. The sentence appears strained because NAN is not a particularly familiar name and because who can fan whom is not a concern of moment to beginning readers. Further, the sentence may contain grapheme-phoneme irregularities in ordinary discourse. For instance, CAN in this sentence would ordinarily be pronounced /ken/ or /kɨn/ in American dialects.

More serious, however, are the irregularities that occur even when spelling patterns are considered separate from ordinary speech. A student who has learned to associate /ət/ with -UT will presumably be more likely to recognize CUT, HUT, JUT, etc. However, he may experience difficulty with PUT. As long as instruction is based on phonemic correspondences to graphemes, exceptions will be encountered.

On the other hand, English orthography may be more closely rule-governed than the number of exceptions to regular grapheme-phoneme correspondences suggest. This possibility is indicated in extensive empirical studies of English orthography by Hanna, Hanna, Hodges, and Rudorf (1966), and Venezky (1967, 1970) and in the gene[illegible]lish phonology of Chomsky and Halle (1968) who introduce the concept of lexical representation. What is necessary is to decide what is meant by regularity in the structure of English orthography and what its implications are for reading instruction. A seminal investigation in this area was that of Venezky and Weir (1966) who demonstrated considerable regularity in the relationship of English orthography to spoken language provided one looks beyond direct grapheme-phoneme correspondences. This work had a significant influence on the design of the 1500-system curriculum, resulting ultimately in the idea of a vocalic center group (Hansen and Rogers, 1968) which was assumed to be the minimal pronunciation unit rehearsed by the reader in order to build associations between orthography and oral language.

A vocalic center group was described by Rogers (1967) as a vowel nucleus with 0-3 preceding consonants and 0-4 following consonants and by Hansen and Rogers (1968) as "the optimally minimal sequence within which all necessary rules of phonemic co-occurrence can be stated" (p. 74). From Rogers' description, then, the vocalic center group looks very much like a syllable and, in fact, he suggested that the "reader will not be seriously misled if he associates the units which result from standard dictionary syllabification with the vocalic center groups" (p. 16). From the Hansen and Rogers description it is clear that the

vocalic center group is phonologically rather than semantically motivated; it is expected to be the minimal orthography required to identify the sound sequence that the orthography is intended to represent. Moreover, vocalic center groups must conform to the orthographic-sound limitations of the language in which they occur: RAD, SED, and STREMPTS are all legitimate vocalic center groups according to Rogers whereas SLRAP, TENPS, and MEALK are not.

A more serious problem with the vocalic center group notion is illustrated by its assumption, for instance, that a learned association between the letter sequences MAP and TEN and their pronunciation would facilitate association of TAP and MEN to the appropriate pronunciation as Rogers suggests (p. 15). However, MAP and TEN are vocalic center groups, and therefore are the minimal orthographic units required for establishing the appropriate sound sequences. If they are indeed the minimal orthographic units, it is difficult to see how learning them would yield any positive transfer to the task of learning TAP and MEN; there must be a smaller unit of orthography involved, and this distinction underlies a basic difference between the 1500 curriculum and the PDP-10 curriculum. The 1500 curriculum took the vocalic center group as the basic decoding unit to be taught and the PDP-10 curriculum took the spelling pattern as the basic decoding unit to be taught.

Given that both curriculums were intended to increase decoding skills through the presentation of regular letter to sound relationships, and to supplement ordinary classroom instruction, it is notable that they differed in their selection of sight word vocabulary. The 1500 curriculum limited itself to items that were either vocalic center groups

or combinations of vocalic-center groups. Despite considerable emphasis on spelling patterns in the PDP-10 curriculum, the complexities in English orthography and in the classroom materials the curriculum was supposed to supplement were recognized. Vocabulary items with fairly complex spelling-to-sound relationships but with high frequencies in first through third grade reading materials were taught in a direct paired-associate manner.

The 1500 System Curriculum

Overview

The architecture of any computer system intended for CAI is notable not primarily for the curiosity that may be occasioned by the bits, bytes, and lights of a new technology, but for the boundary conditions it imposes on curriculum design. The 1500 System was an impressive technological innovation, but, like any instructional medium, it imposed limits on the instructional presentations it could support. There was for instance, no direct way to check by computer a student's ability to produce the sound sequence represented by displayed orthography, yet this ability was the principal objective of the program. Both the audio and the photographic random access mechanism were based on serial access devices, tape and film reels respectively, making the positioning mechanism quite slow relative to the random access speeds currently available from digitized speech and videodisk technology. Arithmetic operations within the Coursewriter II language were cumbersome (no floating point was available), and the optimization techniques discussed by Atkinson (1972, 1974), or the student modeling techniques based on

parameter estimation discussed by Suppes, Jerman, and Brian (1968) and by Fletcher (1975) could not have been implemented. Preparation of line drawings for display on the CRT was a slow process, and facile illustration of a point with a graphic presentation such as a classroom teacher might easily improvise using a blackboard was out of the question. The point of these remarks is that computer system design has direct implications for CAI. The design of the Stanford CAI reading curriculums was shaped both by the body of assumptions concerning initial reading instruction discussed earlier and by the nature of the computer systems used. The former is often noted in comments on the Stanford developments, the latter is usually neglected.

The instruction presentation strategy of the 1500 curriculum was 'tutorial' and based on the intrinsic branching approach to programmed instruction recommended by Crowder (e.g., 1959). Many, if not all, responses to items in this approach are analyzed to determine if a student needs remediation, if he should proceed to the next item, or if he should skip several items ahead. Most lessons in the 1500 curriculum were preceded by a screening test on the basis of which a student could pass over large amounts of information in the lesson. On the other hand, many items in the 'mainstream' of the lessons were associated with remedial material so that a student who performed poorly could be given extra practice on those aspects of the material with which he appeared to be having difficulty.

The curriculum was divided into three catagories of material: decoding, comprehension, and motivational material. A description of these categories follows.

Decoding Materials

The decoding materials included four activities: letter identification, word matching, matrix building, and compound word identification.

Letter Identification. No direct attempt was made to teach the names of letters. It was assumed that letter names were at odds with the dominant sound they represent and teaching letter names would confuse students who were being taught to decode. Three tasks were typically presented: (1) single letter matching in which the student was to indicate with a light-pen response which of two or three letters on the CRT was the same as a letter displayed by the projector; (2) letter string matching in which the student was to indicate with a light-pen response which of two or three letter strings on the CRT was the same as a letter string displayed by the projector; and (3) a same-different task in which the student was to indicate if two letters or letter strings displayed on the CRT were the same or different.

Word Matching. This section consisted of paired-associate tasks in which the stimulus was the verbal pronunciation, orthography, and/or pictorial representation of a word, and the response was the identification of the appropriate word in a list displayed by the CRT. The student indicated his choice by touching it with his light pen. Layout for word matching is shown in Figure 1. A cue fading technique was used for this activity, and four problem types were developed to correspond to the following arrays of cues: (1) picture, orthography and audio (as in Figure 1); (2) picture and audio; (3) picture only; (4) audio only.

Even though there was no voice recognizer on the system, students were told to "touch and say" pronouncable responses. Because the system responded only to "touch" and not to "say", students, quite reasonably, stopped making oral responses to these instructions early in the curriculum.

Insert Figure 1 about here

Matrix Building. The core of each lesson was the matrix building activity. Alliteration patterns, i.e., initial consonants, were presented in rows, and rhyming patterns, final units, were presented in columns as shown in Figure 2.

A matrix was constructed one cell at a time. The initial consonant(s) of a word were called the initial unit and the vowel and the final consonant(s) were called the final unit. Initial units in the 1500 curriculum differed from those of the PDP-10 curriculum in which spelling patterns, initial or final units, were never presented without an accompanying vowel. The intersection of an initial unit row and a final unit column determined the entry in any cell.

Insert Figure 2 about here

The problem format for the construction of each cell was divided into four parts: Parts A and D were standard instructional sections and parts B and C were remedial sections. Parts B and C were branched

Compound Word Identification. The approach to compound words assumed a learning-transfer process in which the student knew how to read one of the two elements that formed a compound word. The student was expected to review the known word and learn both the unknown part of the compound and the compound itself. Additionally, he studied the conventional meaning of the compound word and its role in a semantically rich sentence.

Compound words initially introduced were composed of two known monosyllables, e.g., bat and man were mastered prior to the presentation of the compound batman. Sequences introduced later were composed of five compound words in which only one of the elements was known. Compound words were selected according to three criteria: (1) frequency in initial reading materials, (2) imaginative possibilities yielding semantically rich context sentences, and (3) opportunity to vary the known word in initial and final position in the five compound words (e.g., hatbox, firehat, hatband, etc.).

Comprehension Material

The comprehension material focused on the understanding of sentences and included four sections: usage, form class, inquiries, and sentence initiators.

Usage. The usage section was intended to cue an appropriate set of semantic associations for lexical items presented. A list of words was displayed by the CRT. Definitions were given auditorally and the student was expected to identify the word that matched each definition with a light pen response. The definitions were chosen under two constraints: (1) If the word appeared in the Rainbow Dictionary

to from Part A and were presented independently or in combination. Part B provided remedial practice on initial units. Part C provided remedial practice on final units. In Part A, the student was instructed to "touch and say the word that belongs in the empty cell." The answer choices were designed to identify three classes of errors:

1. The initial unit was correctly identified but the final unit was not (e.g., BAG in Figure 2, Part A). The student was branched to Part C and then back to Part A.

2. The final unit was correctly identified but the initial unit was not (e.g., RAT in Figure 2, Part A). The student was branched to Part B and then back to Part A.

3. Neither the initial unit nor the final unit was correctly identified (e.g., RAG in Figure 2, Part A). The student was branched to Part B, then to Part C, and then back to Part A.

If the student's answer was correct he was branched to Part D.

Individual cell building was continued until the matrix was complete. The matrices in the lesson material contained from 6 to 12 words and nonsense syllables. Nonsense words were considered legitimate cell entries if (1) they were occurrent English syllables, (2) they did not represent unconventional spellings for common monosyllabic words--for example, sed represents a regular spelling for the initial English syllable in words such as sediment, but it was not presented in matrix format since it was a nonstandard spelling for the homophonous monosyllabic word said, and (3) they comprised less than 40 percent of the total cell entries.

(Wright, 1959), all the meanings defined in that dictionary were used; (2) If the word did not appear in the Rainbow Dictionary but appeared in the Thorndike-Barnhardt Beginners' Dictionary (1964), at least one of the definitions, depending on frequency and usefulness, was used. If the word did not appear in either dictionary, it was not included in the usage section nor used in succeeding lesson materials.

A strict 'dictionary definition' format was avoided in defining word items. Standard definitions were reconstructed to stress functional meanings. For example, the word BAT might have the following dictionary definition: "a stout wooden stick or club, used to hit the ball in baseball, cricket, etc." In the lesson materials this definition was reformulated: "Touch and say the word that means something you might use to hit a baseball."

Form Class. The form class section was intended to cue an operational knowledge of syntactic associations for lexical items presented. A typical item of this sort is shown in Figure 3. The student was to indicate with a light-pen response ("touch and say") which word "made sense" in the sentence. Usually, one word was correct, one was of the correct form class but semantically inappropriate, and one was inappropriate both because of its form class and its semantic associations.

Insert Figure 3 about here

Inquiries. In this section, the student was asked to identify lexical items in a displayed sentence that answered a given question. For instance, there might be two items based on the sentence "John hit

the ball." One item might require the student to indicate with a light-pen response ("touch and say" again) who hit the ball. Another item might require the student to indicate what John hit.

Sentence Initiators. This section was intended to teach students timing, pitch, and stress contours so that they could read sentences with intonation patterns commonly found in speech. High frequency sentence initiators (IT'S A, THAT'S A, THEY'RE) were selected from Carterette and Jones' (1965) list of multi-word units uttered by six-year old children during free discussion. These initiators were combined with words already presented to form sentences which were then displayed to the students. The idea was to use the timing features of the computer system in the following sequence: (1) A sentence was displayed by the CRT and the student was given two seconds in which to attempt an oral reading and record it on the audio device; (2) The audio device played a reading of the sentence; and (3) The student was given two seconds to repeat the reading of the sentence.

Motivational Material

These materials consisted of games, rhymes, and stories. Games were sequenced into each lesson and were intended to exercise developing competencies. Rhymes were presented as listening activities to illustrate the rhyming and alliterative sounds of words and to demonstrate the rhythmic use of language. Stories were read to the students using the audio device and displayed by the CRT, sentence by sentence so that students could follow print as it was being read.

Tenets

Rogers (1967) listed some tenets of the 1500 curriculum that are repeated here by way of summary.

1. Reading and spelling should be taught independently. This tenet was adopted on the assumption that most reading obstacles are unrelated to spelling obstacles.

2. Reading should be initiated with a decoding or transfer stage during which the student learns to associate graphic patterns with speech sequences. This tenet led to the next.

3. The association of sight to sound is initially effected between letter patterns and vocalic center groups and is meaning independent.

4. The sequence of items to be presented for association learning should be determined primarily by a difficulty scaling of vocalic center groups as documented by Hansen and Rogers (1968). Four principles for ordering vocalic center groups were ennunicated by Rogers:

a. Groups containing single consonant elements should be introduced before those containing consonant clusters (TAP before TRAP);

b. Groups containing initial consonant clusters should be introduced before those containing final consonant clusters (TRAP before TARP);

c. Groups containing short vowels should be introducted before those containing long vowels (TAP before (TAPE);

d. Single vocalic center group sequences should be introduced before multiple sequences (TRAP before TRAPPER).

Notably, principles (a) and (b) are at variance with results documented by Fletcher (1973) which indicated that in a pronunciation task CVC and

CVCC items are about the same difficulty and that both are significantly easier than CCVC and CCVCC items which, in turn, are about the same difficulty.

5. Every graphic pattern should be presented as a member of a rhyme (final unit) set and an alliteration (initial consonant) set, the distinguishing characteristics of these sets being displayed in a matrix format.

6. Word items presented in matrix format should be immediately introduced in sentential contexts that emphasize their morphological, syntactic, and semantic functions.

7. Patterened word items should appear in poems, stories, essays, and descriptions in which the features of pronunciation, grammatical function, and meaning are shown to function together to convey the writer's intention to the reader.

The PDP-10 Curriculum

Overview

The student terminals in the PDP-10 teletypewriter curriculum were obviously restrictive. Teletypewriters are noisy and slow (10 characters a second is an annoying rate of display when mildy sophisticated use of alphanumerics is necessary), but their price was right and they provided hard copy for review by students, proctors, and teachers. Notably, there was an effort to design a curriculum sufficiently inexpensive for schools to purchase. It is also notable that in comparing the 1500 curriculum to the PDP-10 curriculum, the limitations of teletypewriters were compensated for by the digitized audio capability and

by the power of the computer timesharing system itself. The audio output system had more capability and flexibility than the 1500 audio system, and the operating system provided more on-line computational capability than the curriculum designers needed. However, the computer operating system flexibilities required were not all available as 'off-the-shelf' items. An entirely new disk file system was developed to support student data recording and the audio system. Capabilities were also developed for system level character editing, student mode program execution, high speed line multiplexing, and for generating re-entrant code from the higher-level languages available.

The instruction presentation strategy was 'drill and practice' and based on the strands approach to CAI developed and described by Suppes (e.g., 1967). The program was divided into the seven parts or strands shown in Table 1.

Insert Table 1 about here

The term <u>strand</u> was used to identify a basic component skill of initial reading (with the exception of Strand 0). Students moved through each strand in a roughly linear fashion. Branching or progress within strands was criterion dependent; a student proceeded to a new exercise or new material within a strand only after he attained some (individually specificable) performance criterion in the current exercise or material. Branching between the strands was time dependent; a student moved from one strand to take up where he left off in another

after a certain (again, individually specifiable) amount of time regardless of what criterion level he had reached in the strands. Within each strand there were two to three progressively more difficult exercises that were designed to bring students to fairly high levels of performance. The criterion procedure generally required two consecutive correct answers for each item and one errorless pass through the list of items constituting an exercise.

Entry to each strand depended upon progress in earlier strands. For example, the letter-identification strand started with a subset of letters used in the sight word strand. When a student in the letter-identification strand exhibited mastery over the set of letters used in the first several words of the sight-word strand, he entered the sight-word strand. Entry into both the phonics and spelling pattern strands was similarly controlled by the student's placement in the sight-word strand. Thus, a student could work in several strands simultaneously. Once he entered a strand, however, his advancement within that strand could be independent of his progress in other strands.

Most students spent two minutes on each strand and the length of their daily sessions was ten minutes. The time each student spent in any strand and the session length were parameters that could be uniquely specified. Sufficient information was saved in student restart records, to assure continuation from precisely those conditions that existed at sign-off.

The strands were comprised of sets of three curriculum items, and it was in these sections that a student needed to reach criterion before

progressing in the strands. Each section was presented in either two or three separate exercises. In each exercise the three items of the section were presented in random order until the student achieved criterion. A student who already knew the material of a particular exercise could leave that exercise after only six responses, which could take him as little as 30 seconds. Students made 5-12 responses a minute on the program.

Students received instruction for the exercises by means of the digitized audio system. The student would input his responses on the teletypewriter. When he completed his response, he pressed the space bar which returned control of the terminal to the computer for response evaluation. If the student discovered an error in his response, he could press the rubout key before pressing the space bar and the entire problem was presented again for a second trial. If a student pressed the rubout key more than three times before entering a response, he received a "too many rubouts" message. Timeouts were also used. If a student took more than 10 seconds to type any character in his response, he was given a "too much time" message and his answer was treated as incorrect. Students received a printed record of the work completed at the end of each session. Classroom teachers also received daily a printed report on progress achieved by their students. Kindergarten and first-grade children adapted quickly to use of the keyboard and had no difficulty in typing the relatively short responses (maximum of 8 characters) required.

Description of the Strands

Strand 0 - Machine Readiness. Readiness materials were prepared to acquaint students with the manual skills required to interact with the program. The readiness strand attempted to teach students to sign themselves on the program without proctor supervision. To sign on the reading program, a student typed R (for reading) and his assigned student number. He then typed a space followed with his first name and another space. The program responded by typing the student's last name. If the last name was correct, the student typed a space and the program proceeded with his lesson. To leave the readiness strand, a student was required to perform the sign-on procedure with no more than one error. The readiness strand differed from the other strands in that branching from it was criterion dependent rather than time dependent.

Strand I - Letter Identification. Each letter was presented twice in the letter strand. For the first pass through the alphabet, grouping of letters in three-letter sections was designed to minimize visual confusion. For the second pass through the alphabet, grouping was designed to maximize visual confusion. In all cases, sections were designed to minimize auditory confusion.

Three types of exercises (copy, recognition, and recall) were used throughout the letter-identification strand. These exercises are illustrated in Figure 4. In the first exercise, a letter was typed and the student was requested to type the same letter. Random presentation of the three letters in a section continued until the student reached criterion for Exercise 1 at which time he was advanced to Exercise 2 of the letter strand. After

each presentation in the second exercise of the letter strand, the order of the three letters in the display was randomly changed, and the exercise was repeated for another target letter. Upon achieving criterion for each of the letters, the student proceeded to Exercise 3. When the student achieved criterion on the three letters in the section in Exercise 3, he returned to Exercise 1 with a second set of three letters.

Insert Figure 4 about here

Throughout the curriculum, if the student responded correctly he proceeded to the next presentation. If he responded incorrectly or exceeded the time allowed for a response, the teletypewriter displayed the correct response and proceeded to the next presentation. When the student responded correctly, he received randomly scheduled audio reinforcement messages. The usefulness of 'variable-interval reinforcement' has been established as a method of achieving performance that is stable and highly resistant to extinction. The effect of the audio reinforcement messages in the teletypewriter curriculum was unclear. It is doubtful that they comprised the principal reinforcement mechanism 'operant' in the curriculum. Be that as it may, they continued to be used, and included messages like "fabulous", "outstanding", and recorded clapping and cheering. They were, at least, entertaining.

When a student met criterion on a specific number of letters (i.e., those required for the first words in the sight-word vocabulary of Strand II), he began Strand II and continued to work simultaneously in both Strands I

and II, but at different levels of difficulty within each strand.

Strand II - Sight-Word Vocabulary. Strand II provided practice on a vocabulary that was introduced and taught in the classroom and contained words common to several basal reading texts and sight-word lists. The vocabulary was presented in sections of three words presented in two different exercises (copy and recognition) which are illustrated in Figure 5.

Insert Figure 5 about here

When the student achieved criterion in Exercise 1 for each of the three words forming the section, he began Exercise 2. As in Exercise 2 of the letter strand, the order of items that comprised the display was random in each presentation in Exercise 2 of the vocabulary strand. When the student met criterion for each new word in each of the two exercises, he proceeded to the next section of three words and began again on Exercise 1. The selection of items for review and presentation in the vocabulary strand grew progressively more complex. As Atkinson (1974) showed, the curriculum was evolving toward a presentation strategy that was based on optimization notions of control theory. Discussion of this process is a feast-or-famine proposition and famine is the proposition selected here. The interested reader is referred to Atkinson (1974) and Atkinson, Fletcher, Lindsay, Campbell, and Barr (1973) for discussion of this process in the vocabulary strand.

Strand III - Spelling Patterns. The spelling pattern strand was designed to provide direct and explicit practice with English spelling

patterns. Although all the spelling patterns presented in this strand were chosen from those taught in the phonics strand, new words were used. A section for this strand consisted of three monosyllabic words, such as CAT, BAT, RAT, each of which incorporated the same (final unit) spelling pattern. Copy and recall exercises were used in this strand and are illustrated in Figure 6.

Insert Figure 6 about here

Strand IV - Phonics. Exercises in the phonics strand concentrated on initial and final consonants and medial vowels. Students were never required to rehearse or identify consonant or vowel sounds in isolation. The smallest unit of presentation was a dyad, i.e., a single vowel-consonant or consonant-vowel combination. Copy, recognition, and word building exercises were used in the phonics strand and are illustrated in Figure 7. As in the preceeding strands, students worked with a section of three units and had to meet criterion for each spelling pattern in each of the exercises before proceeding to the next section.

Insert Figure 7 about here

The audio reinforced the sound values of the spelling patterns with randomly selected examples from three samples — two monosyllabic and an easily identifiable polysyllabic word. However, the word to be typed by the student in Exercise 3 (word building) was always one of the two

monosyllabic exemplars.

The teletypewriter curriculum was unusual among spelling pattern curriculums in two respects. First, other curriculums present spelling patterns implicitly. Spelling patterns that are not themselves words (-AB) are presented only as components of words (CAB, TAB, SLAB); they are never presented explicitly by themselves. The Stanford CAI program presented spelling patterns both implicitly in the spelling strand and explicitly in the phonics strand. Second, the spelling patterns chosen for other curriculums are usually final consonant, or final unit, patterns; they are syllable endings (-AB -AN -AT) rather than syllable beginnings (BA- NA- TA-). The Stanford CAI curriculum presented both initial unit and final unit spelling patterns.

The spelling patterns in the curriculum were grouped into four categories: -VC, CV-, -VVC, and CVV-. Each of the categories was divided into subcategories according to vowels. For example, category CV- consisted of subcategories Ca-, Ce-, Ci-, Co-, and Cu-. Category -VC also included the spelling patterns -VC$\not{e}$, where $\not{e}$ denotes a silent e at the end of a word. The students studied only one subcategory of spelling patterns at a time. Each item was successively presented in the exercise formats described. When the requisite number of items within a subcategory passed criterion for Exercise 3, a decision was made to determine which category and subcategory the student should study next. The student began in category -VC, and when the criterion was met, he was transferred to one of the categories CV-, -VVC, or CVV- with probability P_2, P_3, or P_4, respectively, or was retained in category -VC with probability P_1.

The student always transferred back to category -VC when he finished one of the other categories.

Branching between vowel subcategories within each category occurred in a round robin fashion. The branching scheme emphasized the -VC category. Usually P_1 = 1/2, which meant the student studied items in the -VC category for 2/3 of the total instructional time allocated to the phonics strand. This emphasis reflected results documented by Fletcher (1973) indicating that practice with final units (-VC) produces better performance than practice with initial units (CV-). Branching in the phonics strand is discussed more fully by Atkinson (1974) and Atkinson, Fletcher, Lindsay, Campbell, and Barr (1973).

<u>Strand V - Word Comprehension.</u> Strand V provided practice on the meaning of words introduced in the sight-word strand. A section consisted of three groups of three words. Each word was associated with one of several categories. The presentation displayed three words followed by a request to type a word of a particular category. The strand used a single exercise format illustrated in Figure 8. The order of the three words presented was random and the target word, with its associated category, was randomly chosen from those displayed.

Insert Figure 8 about here

<u>Strand IV - Sentence Comprehension</u>

A section in this strand consisted of three sentences (or phrases) with one word missing in each. Displayed with each sentence were three words — two were distractors and one correctly completed the sentence.

As in the 1500 curriculum, one of the distractors was of the correct form class, but was either semantically or syntactically unacceptable in that it broke a subcategorization rule. The second distractor was unacceptable both semantically and syntactically. The strand had a single exercise format at [illegible] level 9.

Insert Figure [illegible] about here

Final Comment

This paper briefly discusses twelve years of CAI development in beginning reading, some of which met with mild and occasionally dramatic success. However, the use of computers to teach beginning reading may only have begun. By way of summary, then, it seems appropriate to list a number of observations on this development that might be usefully considered by future investigators. These observations follow in no particular order.

1. Both curriculums were intended to supplement ordinary classroom instruction. The fanfare that greeted the introduction of CAI anticipated a minor revolution in classroom practice as a result of its appearance. Despite extensive workshops, individual conferences, and daily reports on the progress of individual students, very few changes in the practice of classroom teachers were observed that could be attributed to CAI. Student achievement increased under CAI, but the impact on classroom practice was minor. Therefore, a supplemental role appears appropriate for CAI in beginning reading.

2. There was a shift in instructional strategy away from a tutorial approach toward a drill-and-practice approach. In beginning reading, as in other curriculum areas, it was difficult to anticipate and prespecify what problems a student might have with the material presented and what remedial material would help the student out. It was apparent that CAI has a unique capability for bringing about the rapid, automatic reading responses discussed by Fries (1963) and by LaBerge and Samuels (1974), and the Stanford curriculum increasingly emphasized these responses. Drill-and-practice may be a regrettable term evoking images of school as a sweat shop, but it describes the approach taken and it was impossible to avoid the observation that the students enjoyed the CAI presented.

3. There was no discernable drop in student achievement resulting from the reduction in CAI terminal capabilities experienced in shifting from the 1500 Instructional System to the PDP-10 based system. The detailed instructional theory telling how best, or even optimally, to use the full capabilities of the 1500-system student terminals simply did not and does not exist. It is possible that the best instructional ideas available applied to both systems would make relatively little difference in instructional outcome and would fail to justify the great differences in their costs. For that matter, the necessary attention to each letter in the typed responses required by the PDP-10 curriculum may have been responsible for some of its success whereas the facile light-pen responses used in the 1500 curriculum may have reduced its instructional effectiveness.

4. Techniques of optimized instruction were increasingly used. Promising trends in the development of the reading curriculums were the

experimental applications of control theory (Atkinson, 1972), quantitative models of memory (Fletcher, 1975), and techniques of inequality aversion (Jamison, Fletcher, Suppes, and Atkinson, in press). As Atkinson's (1974) overview of these techniques applied to beginning reading instruction indicates, work in this area has barely begun, but the utility of these techniques and the initial research results appear to be well established.

5. Curriculum development became less theory driven and more pragmatic. This trend was particularly evident in decoding instruction: letter names were not used in the 1500 curriculum but they were in the PDP-10 curriculum (although neither curriculum presented letter sounds in isolation); spelling was not taught in the 1500 curriculum, but it was taught in the PDP-10 curriculum; only 'regular' words and non-words were taught in the 1500 curriculum, but 'irregular' words were presented as vocabulary items in the PDP-10 curriculum and non-words were not taught.

6. Use of games, stories, and other motivational materials decreased. The computer system was increasingly viewed as an expensive, valuable resource and techniques for its efficient use gradually increased in relative value. This trend was aided by the students' enthusiasm for CAI which did not appear affected by the increasing emphasis on efficiency in the curriculum.

7. An emphasis on decoding skills was maintained throughout the development. Literal and interpretive comprehension instruction can be presented by computer as the fourth through sixth-grade CAI reading

curriculum documented by Fletcher and Suppes (1972) illustrates, but it was never the judgment of the Stanford group that the proportion of comprehension instruction to decoding instruction should have been increased in the beginning reading programs. Notably, Fletcher and Atkinson (1972) found that their sample of CAI beginning reading students scored significantly higher on the paragraph meaning subtest of the Stanford Achievement Test than did a control sample of non-CAI students.

8. From an operational standpoint, it was simpler to schedule CAI in a central location for all members of a classroom at one time than it was to present CAI to one student at a time, using single terminals installed in classrooms. The setting for the Stanford curriculums consisted of a single room in which all the computer terminals used by the school were installed and which was staffed by an experienced CAI proctor. For older children, it might have been reasonable to distribute terminals to individual classrooms, but it was not reasonable for the students in grades K-3 who used the Stanford CAI.

9. Beginning reading achievement was about the same for boys and girls under CAI. This result was first announced by Atkinson in 1968, and it persisted throughout the history of the development. To some extent this result was presaged by McNeil's (1964) finding of superior reading achievement by boys over girls in kindergarten using programmed reading materials but it was still surprising given well established (e.g., Maccoby, 1966) expectations of superiority in primary-school girls over boys for verbal intellectual functioning.

10. A favorable economic argument can be made for CAI. Using computer cost data of the late 1960's and assuming system support for

1000 terminals, Jamison, Fletcher, Suppes, and Atkinson (in press) were able to present a favorable argument for the cost-effectiveness of the Stanford PDP-10 beginning reading curriculum. With the recent, dramatic reductions in the costs of computer processing and memory, it seems likely that a stronger economic argument could be made for CAI assuming a much smaller computer system.

11. Computer operating systems have fundamental implications for the type of CAI they can support. Although considerable effort has been expended in the design of programming language for CAI, little attention has been paid to the design of computer operating systems for CAI. Some preliminary notions were documented by Fletcher and Schulz (1973), but considerably more should be done to identify appropriate specifications for CAI operating systems.

12. Although the strands approach was originally developed for arithmetic CAI, it is a powerful and relevant technique for beginning reading instruction as well. Some general discussion of the strands approach was presented by Suppes (1967), and it was the approach used in the PDP-10 curriculum described above. The approach appears to be of significant, general utility in the design of CAI and deserving of attention from educational researchers.

One conclusion from the Stanford projects might be that CAI has genuine possibilities for the improvement of beginning reading instruction and that the work of the Stanford development should be continued. Like many research efforts, the projects raised more questions than they answered. However, if the central problem in beginning reading

instruction is to make it sensitive, on a moment-to-moment basis, to the individual needs of students, then CAI may be the most cost-effective alternative for large-scale solution of this problem.

Figure Captions

Figure 1 1500 Curriculum Word Matching Display

Figure 2 1500 Curriculum Matrix Displays

Figure 3 1500 Curriculum Form Class Display

Figure 4 PDP-10 Curriculum Letter Identification Exercises

Figure 5 PDP-10 Curriculum Sight-Word Vocabulary Exercises

Figure 6 PDP-10 Curriculum Spelling Patterns Exercises

Figure 7 PDP-10 Curriculum Phonics Exercises

Figure 8 PDP-10 Curriculum Word Comprehension Exercise

Figure 9 PDP-10 Curriculum Sentence Comprehension Exercise

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Footnote

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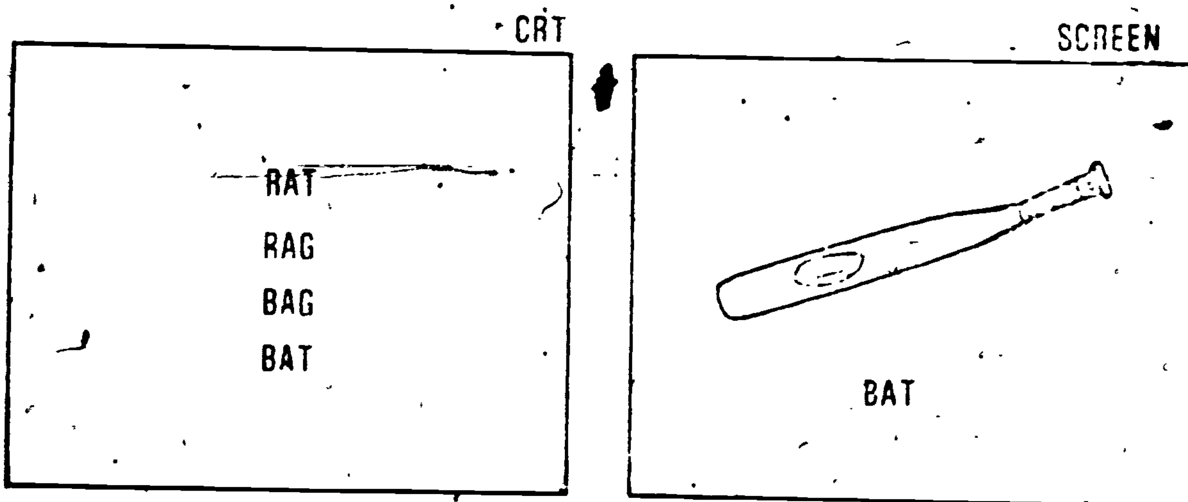
Table 1

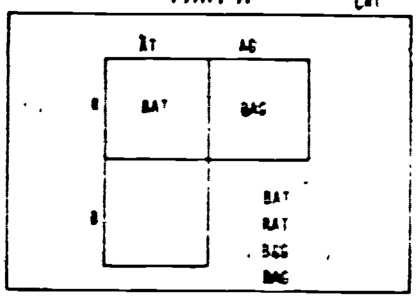
PDP-10 Curriculum Strands

STRAND	TITLE
0	USE OF TELETYPEWRITER
I	LETTER IDENTIFICATION
II	SIGHT-WORD VOCABULARY
III	SPELLING PATTERNS
IV	PHONICS
V	WORD COMPREHENSION
VI	SENTENCE COMPREHENSION



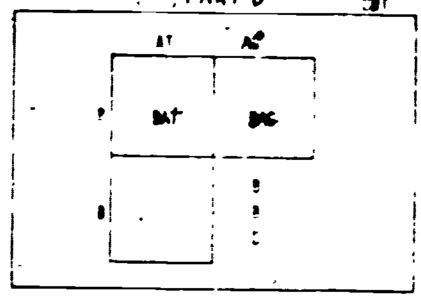
"LOOK AT THE PICTURE AND THE WORD. THE WORD IS BAT.
HE HIT THE BALL WITH THE BAT. TOUCH AND SAY BAT.

PART A



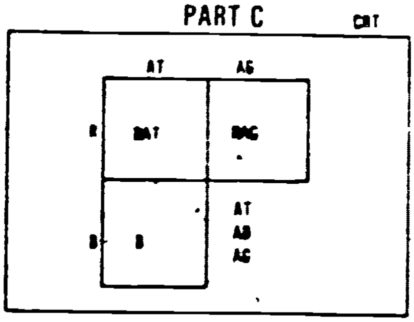
"TOUCH AND SAY THE WORD THAT BELONGS IN THE EMPTY CELL."

PART B



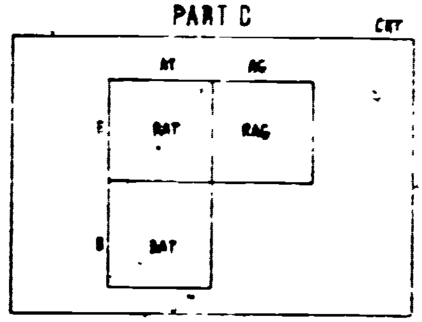
"TOUCH THE INITIAL UNIT OF THE EMPTY CELL."

PART C



"TOUCH AND SAY THE FINAL UNIT OF THE CELL."

PART C



"YOU HAVE PUT BAT IN THE CELL. TOUCH AND SAY BAT."

CRT

	BAT	
THE CAT CAN	TAN	AT THE BAG
	SAT	

"TOUCH AND SAY THE WORD THAT BELONGS IN THE SENTENCE."

	DISPLAY	AUDIO
EX. 1 (COPY):	A	TYPE A
EX. 2. (RECOGNITION):	C B A	TYPE A
EX. 3 (RECALL):	(NO DISPLAY)	TYPE A

	DISPLAY	AUDIO
EX. 1 (COPY):	CAT	TYPE CAT
EX. 2 (RECOGNITION):	SAT CAT BAT	TYPE CAT

	DISPLAY	AUDIO
EX. 1 (COPY):	CAT	TYPE CAT
EX. 2 (RECALL):	(NO DISPLAY)	TYPE CAT

FINAL UNITS

	DISPLAY	AUDIO
EX. 1 (COPY):	—AT	TYPE AT AS IN CAT
EX. 2 (RECOGNITION):	—AT —AD —AB	TYPE AT AS IN CAT
EX. 3 (WORD BUILDING):	—AD —AT —AB	TYPE CAT
	C—	

INITIAL UNITS

	DISPLAY	AUDIO
EX. 1 (COPY):	CA—	TYPE CA AS IN CAT
EX. 2 (RECOGNITION):	CA— FA— BA—	TYPE CA AS IN CAT
EX. 3 (WORD BUILDING):	FA— CA— BA—	TYPE CAT
	——T	

DISPLAY AUDIO

HOUSE BAT GREEN TYPE THE WORD THAT IS AN ANIMAL

DISPLAY	AUDIO
MAD DRIVE SWIM TIM WILL ——— THE CAR.	TYPE THE WORD THAT CORRECTLY COMPLETES THE SENTENCE.

OPEN DISCUSSION OF FLETCHER PRESENTATION

HOLLAND: I have had a running intimate affair with your 1500 program. I have concentrated on your matrix style 1, and I have found that there are a couple of characteristics that trouble me. There is a limited amount of data in the published report, but the data there support the contention that a fair amount of responding, among these four alternatives for each item is essentially random. Maybe, 25% comes from the child simply putting light key on one of the four alternatives at random. Of the data that is nonrandom, there are bases on which the subject can perform correctly without actually doing the task supposedly being taught--namely the phoneme-grapheme correspondence. A deaf child could do pretty well on the program, just on simple visual matching and obviously without phonemes playing any role. The games are very constant; they are repetitive. Once the child learns to pick the one that's got the three letter forms, the child can respond correctly with regard to sound.

Moreover, I was very interested in your observation that the diagnosing and branching didn't work. I have proposed three measurable characteristics for the adequacy of branching decisions--predictive validity of need for some teaching material, the time efficiency of testing and this discriminability of the measures. The 1500 curriculum seems to lack predictive validity as diagnostic items. Children being asked to perform the same main line items without any of the remedial loops show little more than a chance relationship between the two performances. How can prescribing differential teaching material on such data make any sense; and to do so with a two million dollar gadget, and an even larger personnel cost is laughable.

FLETCHER: Well, actually the personnel budget was smaller than the machine

budget.

HOLLAND: Prorated over the years of the project?

FLETCHER: I think so. I wouldn't want to be put in the position of having to defend the 1500 curriculum. I worked on it; I did some of the programming for it; I did some of the data collection for it, but we were feeling our way. This is the first time we tried something like this. We thought we had a brand new device; we brought up a lot of brand new shining ideas to try out on it. I think a lot of them didn't work. It was an interesting effort, and I think we learned a lot from it, but I think we got a lot better when we went to the teletypewriter curriculum. The lessons that we learned, such as those you brought up, carried over into the teletypewriter curriculum. I would like to emphasize that although we had all these shining new gadgets in the 1500 system, and we had a very limited display capability on the PDP-10 system, we knew better how to use the stuff on the PDP-10 system, and I think it was a more effective curriculum in the long run than the 1500 system, because it is not really clear how to use visuals in reading or how to branch and remediate in a criterion sense. Those things are not all that clear, and certainly they're not clear enough for a computer curriculum in which you want to have a very high probability of success.

VENEZKY: Would you say something about what was going on in the classrooms, in terms of the actual reading program, and also something about what you did for teacher training?

FLETCHER: Yes. Teacher training is always a big effort in these things. If you

want these things to succeed--and, as one who has had to worry about the introduction of CAI in schools, I do--teacher training is not something that you can ignore. You have to have a lot of people on your side: teachers, administrators, everyone.

As we began to introduce curricula--including reading curricula--we gave a three-day workshop for teachers right at the beginning of the school year, typically before classes began. We tried to get some sort of credit for the teachers who attended the workshops. We would follow it up two weeks later with a formal presentation of about half a day to a day. Then, periodically, we would station some of our staff in the teachers' lounge. They would sit there with ropes and snares and things. As the teachers came in for a break, our people would hop on them and say things like: "Well, how do you like it? What do you think about it? What complaints do you have? What is good about it?" We had that kind of business going on constantly.

We had teacher reports available to them. In the teletypewriter curriculum, we were able to say very precisely what curricular items they had passed and what vocabulary items they had. The items they hadn't had, of course, were implied from the teacher's guide we gave out. We tried to explain to them why we were doing what we were doing, tried to explain some of the theoretical notions behind what we were doing. In general we made every effort to try to get the classroom teacher to work with us, to work with the curriculum, to tailor the classroom approach to what was going on in the computer. And I would say that about 85% of the time we were unsuccessful. The teachers were willing to assume that it was a reasonably useful effort, that it was doing some good for the kids--it certainly wasn't harming them--and that they were willing to put up with it. But they were not going to tailor their classroom instruction around it.

VENEZKY: Does that mean, in essence, that they just went right on doing what they normally do in reading?

FLETCHER: Yes.

VENEZKY: That is exactly what the Plato reading curriculum did. They were in dozens of schools in Champaign for two or three years, and their experience has been that the teachers think it's wonderful. They love to have it; they are very supportive of it, but they will be damned if they will pay any attention to the results of it.

FLETCHER: Yes, we were in over 30 schools from year to year, and it was the same story. Those 10% who did work with the curriculum fairly nice results. You could tell the difference in the test scores and measures of that sort.

VENEZKY: Do you have any ideas on how to integrate this kind of technology into a program? Do you think you would have to take responsibility for the full reading program to do that?

FLETCHER: I feel that there are limits to what you can do on a computer, very real limits. You have to have a human teacher in the process. In that sense, computer assisted instruction [for elementary school instruction] is going to be supplemental, and probably the best way to use it is in as general a way as possible, as we did. In other words, make it capable of adding something to whatever goes on in the classroom, which is not an easy trick. In some cases, it may be impossible.

WHITE: Back in 1969, some data on the early work with the computers were published. It was very impressive stuff, and I really wondered why no one ever talked about it or dealt with it. Two reports came out of Stanford. One report talked about, I think, the PDP-10 system. The report talked about the drill and practice as a supplement to what the teacher did. The report made some really remarkable claims. In the first case, it said students were achieving test gains, and the system tended to close the gap between high and low students. That is the only system I every heard of doing that. In other words, it seemed to work selectively: It helped poorer students rather than better students. There was a company report that "costed out" the system and put the gleam in the eye of many bureaucrats, because it showed that the system was cost-effective. The claim was that the system could be implemented at an average cost of $70 per child, as I remember. Here you had Title I programs operating at a cost of $160 per child, and nobody was ever able to find any effects. Then you had a gap closing, cost-effective $70-per-child computer supplementary system. I have been really curious over the years about why no one really talks much about that system. No one has ever explained away those reports or said why they never caught hold in the system.

FLETCHER: We didn't do as much of a selling job, as much of an informational promulgating job, as we might have. Considering the amount of data we collected, we did relatively little research and relatively little descriptive study of the data, because we got bogged down in the day-to-day operational requirements of the system. The thing had to be up and running. It had to be up and running at 5:00 A.M. when we were doing stuff on the east coast. We had to be doing that five days a week, and the rest of the time we were working like mad to keep ahead of some of the students.

I remember staying up late at night, for instance, on the 1500 system, to try to get sufficient curriculum in so that we could stay ahead of our very bright students.

But that's what happened, we got bogged down. We underestimated the sheer administrative and logistical problem that is associated with getting a computer system curriculum up.

WHITE: Is this one of those cases that Doug Ellson was talking about yesterday? Do you really have a finding of positive effectiveness that somehow just lays there?

FLETCHER: Yes. And some of the mathematics curricula stuff fits these criteria very well. We would have had to do it [promulgate the positive effectiveness] ourselves; no one else was going to do it for us. And we didn't have any resources. We ran out of energy, time, and money. The project came to an end.

ROSNER: I just wanted to emphasize Dick Venezky's comment here, because I don't think it is reasonable to think that you are going to get classroom teachers to view CAI as an integral part of their program, if it isn't compatible with what they do in the classroom. You can't expect them to go home at night and invent lessons to be compatible with feedback.

Secondly--and I really think this is related to Shep's comments--I watched the CAI program operate in a school (Oakleaf) for about four or five years, and it strikes me that it's very easy to say, "Well, CAI really has limited powers, and we really ought not to think about it any more." It seems to me that almost always, the developers of these things never concede that, maybe, they are not

quite as good at developing instructional programs as they could be, if they would stay with a program longer, and if they would incorporate other resources. I think we have another instance of how a potentially useful instructional device or approach gets thrown out, because the person trying to develop or design the thing doesn't have all the capacities to make it effective, and doesn't concede that other people could probably help....

BARTLETT: In this country, we seem to have two systems. We have a system that designs educational technologies in different ways, and we have a different system that distributes them, the commercial system. The latter usually involves publishers. It seems to me that it's the existence of the two systems that accounts for the fact that a program like Dexter's, for example, doesn't get out into the market. Unless you find a publisher for it, or unless some other organization in the country takes over distribution for it, you are really sunk. You are not really trained to market your programs. In this country, you are not responsible for doing anything more than what you have done. And I think that's a very important issue that no one in the group is really addressing.

FLETCHER: There is an article in a recent issue of the Review of Educational Research by somebody from the University of Pittsburgh, I don't know who it is but he says something about the need for a linking science that will take the results of basic research and put them into the instructional practice. I couldn't agree with that more.

BARTLETT: But nobody seems to care; that's what I find. Nobody is taking responsibility at any point for doing anything about it.

FLETCHER: The funding agencies try, but they try the wrong people. They try to tax the researchers with the problem. They say, "Okay, now that you have done it, you have to promulgate it," and researchers are not trained to do that; that is not their business.

Recess