INSTRUCTION IN INITIAL READING UNDER COMPUTER CONTROL: THE STANFORD PROJECT

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INSTRUCTION IN INITIAL READING UNDER COMPUTER CONTROL:[1] THE STANFORD PROJECT

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There are several major inducements for developing a Computer-Assisted Instructional system for the presentation of initial reading materials to young children. The primary motivation is the potentiality of a detailed investigation of a number of reading hypotheses proposed to account for the acquisition, retention, and generalization of reading skills by young children. A second obvious reason for creating such a system is to establish the feasibility of this mode of instruction with young children. While there is a growing literature from programmed instruction and other resources that indicates that children can profitably learn for short periods of time in an individualized mode, no long-term program has ever been undertaken covering a major portion of the elementary school curriculum. We believe that an evaluation of such a system over an extended period of time is necessary.

Research potential and feasibility are, of course, two sides of the same coin. This dual nature or purpose for projects in Computer-Assisted Instruction is likely to be the rule for some time to come--certainly until much more is known about this new mode of instruction, and until large amounts of material and curriculum suited to its needs are developed. It is our belief that projects in Computer-Assisted Instruction ought to provide detailed data about learning and about curriculum materials; hopefully from this data we can develop a viable "theory of instruction" that will prescribe the conditions under which an instructional procedure optimizes learning (Groen and Atkinson, 1966; Atkinson and Schiffrin, 1967). The Stanford Project was designed to further the development of such a theory. It encompasses investigations of reading materials, learning behavior of young children, a computer system, and inservice and administrational variables. Projects of this type must, of necessity, be tested in the educational setting in which they will be used, and all the variables present in that setting must be considered in both research studies and studies of feasibility.

This research strategy has created a number of problems concerning the organization of the computer hardware, the creation of new reading materials, the adaptation of conventional reading materials, computer coding of the material, and, most importantly, the data analysis of extremely detailed behavioral information on individual children. We will describe, briefly, the computer system, the curriculum and coding, the Project procedures, and its inservice program. Although much of the data will not be analyzed until after the first year is completed, we will present some early results that are available, and a few informal conclusions.

The Stanford CAI System

The Stanford CAI System is designed to present instructional materials to 16 students simultaneously, with the possibility that each student may work on a completely different set of materials,. The reading curriculum that is used is organized so that each child can progress at his own pace, branching along a pathway of materials that reflect his particular competencies. It is to be emphasized that every aspect of the instructional sequence is specified in detail. Every visual display and auditory message that the student might receive, a reply to every response he might conceivably give, a decision procedure for utilizing past performance to determine materials to be presented next, and a coding scheme for storing information on the student's data record must all be planned and prepared for in advance. Furthermore, when an instructional session is finished, a complete record of the sequence of materials presented to the child and his history of responses is available.

Insert Figure 1 About Here

The Stanford CAI System consists of a central process computer (IBM 1800) and accompanying tape-storage units, disc-storage units, card reader/punch, line printer, two proctor stations, and an interphase to 16 student terminals (Figure 1).[2] The central process computer acts as an intermediary between each student and his particular course material which is stored in one of the disc-storage units. A student terminal consists of the following devices:

1) a picture projector
2) a cathode ray tube (CRT)
3) a light-pen associated with the CRT
4) a modified typewriter keyboard, and
5) an audio system which can play pre-recorded messages.

Insert Figure 2 About Here

Visual material may be presented to the child on both the CRT and on the film projector. The CRT can display alphabetic or numeric symbols on a 7" by 9" screen with 16 lines and 40 spaces per line. A limited number of prepared line drawings (pictorial patterns) may also be displayed on the CRT.

Provision has been made for superscript and subscript positioning on all characters. To gain the attention of the student, an emphasis indicator can be placed at any point on the CRT screen to highlight selected items. The indicator may also move along the screen in synchronization with an audio message to emphasize given words or phrases, much like the "bouncing ball" in a singing cartoon.

The pictorial projector is a high-speed sequential 16 mm. film device that presents a still image on a 7" by 9" screen. The projected image may be in color or in black and white. The film images are stored in a cartridge with a capacity of 1024 pictures, any one of which can be randomly selected. The time required to change a film cartridge is less than one minute.

The student receives audio messages via a high-speed sequential control device capable of selecting any message varying in length from one second to 15 minutes. The audio messages are stored in tape cartridges which contain approximately two hours of messages, and like the film cartridge, may be changed very quickly.

The child can respond to the auditory and visual displays via three input modes: a hand-held light-pen, a typewriter keyset, or a microphone recorder. The student uses the light-pen by touching any point on the CRT screen. While the student is placing the pen, an automatically generated brightening of the area on the display aids him in determining the exact location of the end of the light-pen. Coordinates of the location touched by the light-pen are sensed as a response and recorded by the computer.

Each student terminal is also equipped with a keyboard. When the computer activates the keyboard, the student may enter his responses by striking the desired keys and (depending on the problem) may or may not see the characters displayed on the CRT. If desired, a cursor may be used to indicate the screen position of the next character to be displayed to the child.

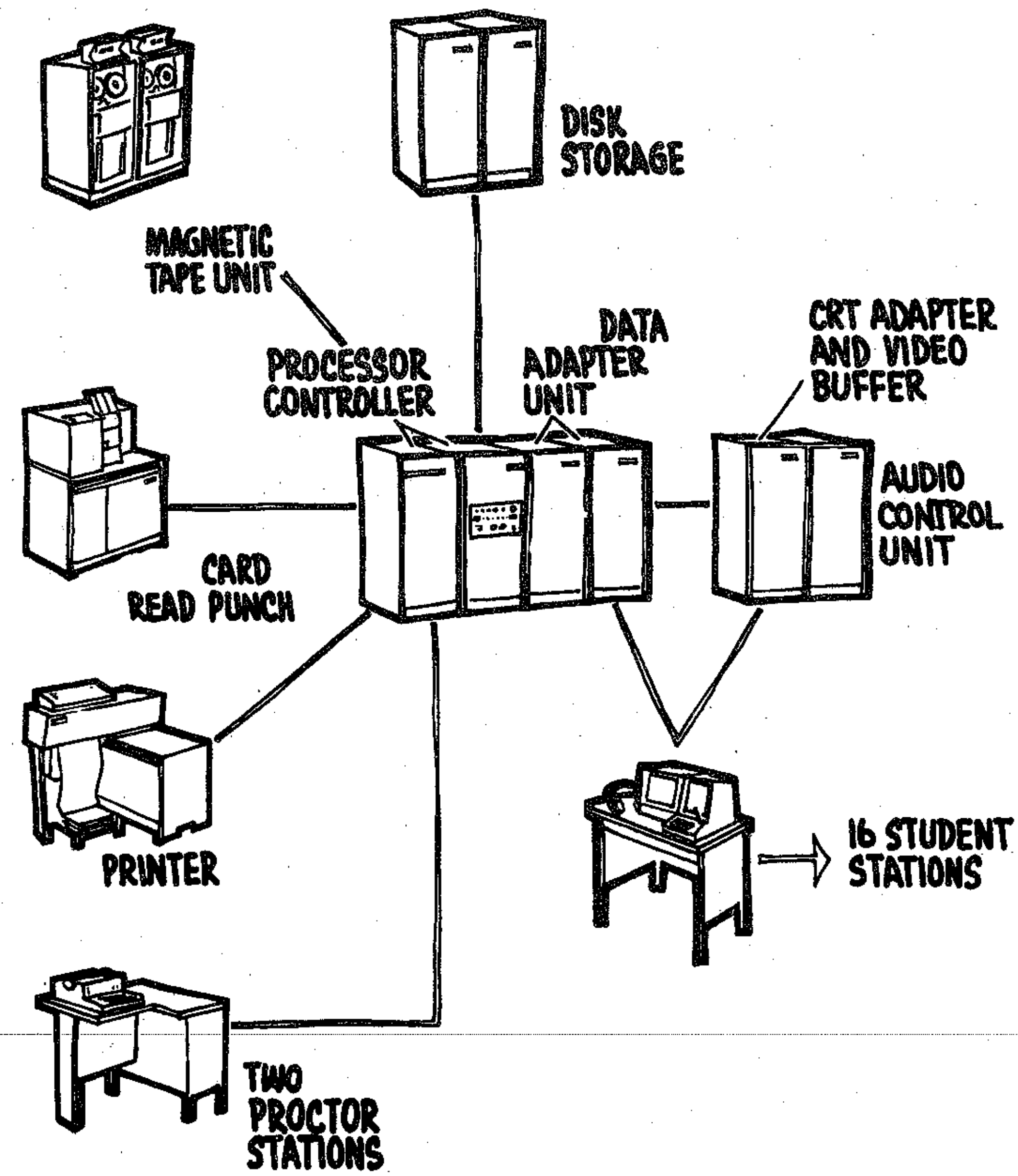

Figure 1. System configuration for computer-assisted instruction.

The third input mode allows the student to use a microphone to make voice recordings that are stored on the audio tape and can be played back at any later time as determined by the particular instructional program. These student recordings may be saved in a manner similar to any tape recording for off-line data analysis.

When the sequence of instructional events requires a student response, a "ready" signal comes on the CRT indicating to the student that the system expects and is prepared for a response entry. The signal is turned off when the response has been completed.

The CAI system controls the flow of information and the input of student responses according to the instructional logic built into the curriculum materials. The sequence of events is roughly as follows: the computer assembles the necessary commands for a given instructional sequence or problem from a disc-storage unit. These commands involve directions to the terminal devices to display a sequence of alpha-numeric symbols and specified pictorial symbols on the CRT, to present a given image on the projector, and to play a particular audio message. After the appropriate visual and auditory material has been presented, a "ready" signal indicates to the student that a response is expected. Once a response has been entered, it is evaluated by the computer and (on the basis of this evaluation and the student's past history) the computer makes a decision as to what material will subsequently be presented. The time-sharing nature of the system allows for a cycle through these evaluation steps in less than one second.

As each response is input into the system, it is recorded in a concise form that identifies the student, the particular problem he is working on, the response made, and the response time. Thus, a complete history is available for each student which can be used in real time to make decisions regarding the instructional sequence, and for later evaluations.

Selection and Preparation of Curriculum Materials

All of the flexibility offered by the system described above can function effectively only when applied to curriculum materials that meet the needs of the students and that "make sense" from a theoretical point of view. The great capacity that the computer has for individualizing instruction requires a great deal of specificity in the design of items, of sequences of items, and of lessons. The Stanford CAI Project has dedicated a large portion of staff time to the preparation of the materials used, and analysis of the individual data records will occupy a major portion of our time in the future.

Space does not permit a discussion of the particular rationale behind the curriculum materials we have used (readers who are interested in a description of the reading materials are referred to Atkinson and Hansen, 1966; Wilson and Atkinson, 1967; Rodgers, 1967; Hansen and Rodgers, 1965). The system is used to present such tasks as letter identification and matching, matrix presentations of phonemes, items designed to teach usage, compound words, polysyllabic words, sentence initiators, and the like. Students learn by means of games, rhymes, stories read to them and stories that they read.

One can more fully realize the magnitude of the work needed to develop such a program if one compares it to the preparation of a conventional basal reader series that is specially constructed to clearly manifest certain hypotheses about reading behaviors and their acquisition and retention.

The first stage in the preparation of materials consisted of clearly formulating the chosen hypothesis that was to be manifested in a given section of the curriculum. This included the formulation and statement of the goals and objectives for the particular material, as well as their supporting rationale. Both the rationale and the objectives had to indicate, with sufficient clarity, that a set of materials was justified. And lastly, the terminology, the visual format, and, most importantly, the overall learning sequence to be followed had to be specified so that one of the Project staff members could assume the responsibility for writing materials in appropriate quantities without inconsistencies or contradictions.

The staff consisted of two psychologists representing the views of learning theory and programmed instruction. The Project linguist pointed out the interrelationships of what is known about the English language as well as contributing ideas concerning psycho-linguistic behavior. A reading specialist provided background about existing reading materials. Teachers with extensive classroom experience contributed their intuition and experience as to how the materials were suited to children with whom they had worked. A computer systems programmer was included to indicate to the group what could and could not be achieved with our system. After preliminary planning, consultants were brought in to provide highly valuable criticism.

After sufficient planning, a staff member was assigned to prepare sample lessons, and these were brought back to Project meetings. Where differences developed, they were resolved by running versions of lessons with small samples of children. With this evidence available, the staff member and an assistant prepared materials by sections for many lessons. After the completion of the written material, it went to a production group. A highly trained group of secretaries then typed and edited the materials, referring errors back to Project staff. This process was facilitated by the use of standard forms.

At this point, the material was sent to three different groups: a group of artists who prepared the illustration plates for the film which accompanies the reading material, a group of professional dramatists who recorded the audio messages associated with the materials, and a group of computer programmers who coded the materials for the computer.

There are a number of special problems that arise in the computer programming required to present a reading lesson. A simple example, explained in some detail, will give the reader some feeling for these problems. The example is from one of the lessons designed to teach the beginning reader both letter discrimination and the meaning of words. A picture illustrating the word being taught is presented on the projector screen. Three words, including the word illustrated, are presented on the CRT screen. A message is played on the audio asking the child to touch the word on the CRT that matches the picture projected on the screen by the film projector. The student can then make his response using the light-pen. If he makes no response within the specified time limit of 30 seconds, he is told the correct answer, an arrow points to it, and he is asked to touch it. If he makes a response within the time limit, the point that he touches is compared by the computer with the correct answer area. If it is within the correct area, he is told that he was correct and goes on to the next problem. If the response was not in the correct answer area, it is compared with the area of the defined wrong answers (in this example, the other two words). If his response is in this area, he is told it is wrong, given the correct answer, and asked to touch it. If his initial response was not in the anticipated wrong answer area or in the correct answer area, then the student has made an undefined answer (i.e., has made a wrong answer, but an unanticipated one). He is given the same message that he would have heard had he touched a defined wrong answer; however, the response is recorded on the data record as undefined. The student tries again until he makes the correct response; he then goes on to the next problem.

To prepare an instructional sequence of this sort, the lesson programmer must write a detailed list of commands for the computer. He must also record an audio tape of all the messages the student might hear during the lesson in approximately the order in which they will occur. Each audio message has an address on the tape and may be called for and played when appropriate (not necessarily in sequential order). Similarly, a film strip is prepared with one frame for each picture required in the lesson. Each frame has an address and pictures can be called for in any order desired.

Table 1 shows the audio messages and film pictures required for two sample problems along with the possible addresses on the audio tape and film strip. What follows is the computer commands required to present two examples of the problem described above, analyze the student's responses,

Table 1: Audio script and film chips with hypothetical addresses

Audio information	
Address	Message
A01:	Touch and say the word that goes with the picture.
A02:	Good. Bag. Do the next one.
A03:	No.
A04:	The word that goes with the picture is bag. Touch and say bag.
A05:	Good. Card. Do the next one.
A06:	No.
A07:	The word that goes with the picture is card. Touch and say card.
Film strip	
Address	Picture
F01:	Picture of a bag.
F02:	Picture of a card.

and record them on his data record. The left column lists actual commands to the computer controlling the instruction. (Labels L1, L2, etc. in the column on the far left indicate points which can be branched to.) On the right is an explanation of the results of the execution of these commands. The first problem is explained command by command; the second problem is explained only in outline.

Commands	Explanation
PR	Problem: Prepares machine for beginning of new problem.
LD 0/S1	Load: Loads 0 into the error switch (S1). The role of switches and counters will be explained later.
FP F01	Film Position: Displays frame F01 (picture of a bag).
DT 5,18/bat/	Display Text: Displays "bat" on line 5 starting in column 18 on the CRT.
DT 7,18/bag/	Displays "bag" on line 7 starting in column 18 on the CRT.
DT 9,18/rat/	Displays "rat" on line 9 starting in column 18 on the CRT.
AUP A01	Audio Play: Plays audio message #A01. "Touch and say the word that goes with the picture."
L1 EP 30/ABCD1	Enter and Process: Activates the light-pen; specifies the time limit (30 seconds) and the problem identifier (ABCD1) that will be placed in the data record along with all responses to this problem. If a response is made within the time limit the computer skips from this command down to the CA (correct answer comparison) command. If no response is made within the time limit, the commands immediately following the EP command are executed.
AD 1/C4	Add: Adds 1 to the overtime counter (C4).
LD 1/S1	Load: Loads 1 into the error switch (S1).

Commands	Explanation
AUP A04	Audio Play: Plays message #A04. "The word that goes with the picture is bag. Touch and say bag."
DT 7,16/→/	Display Text: Displays "→" on line 7, column 16 (arrow pointing at "bag").
BR L1	Branch: Branches to command labeled L1. The computer will now do that command (EP) and continue from that point.
CA 1,7,3,18/C1	Correct Answer: Compares student's response with the area 1 line high starting on line 7, 3 columns wide starting in column 18 on the CRT. If his response falls within this area, it will be recorded in the data with the answer identifier C1. When a correct answer has been made, the commands from here down to WA (wrong answer comparison) are executed. Then the machine jumps ahead to the next PR. If the response does not fall in the correct area, the machine skips from this command down to the WA command.
BR L2/S1/1	Branch: Branches to command labeled L2 if the error switch (S1) is equal to 1.
AD 1/C1	Add: Adds 1 to the initial correct answer counter (C1).
L2 AUP A02	Audio Play: Plays audio message #A02. "Good. Bag. Do the next one."
WA 1,5,3,18/W1 WA 1,9,3,18/W2	Wrong Answer: These two commands compare the student response with the areas of the two wrong answers, that is, the area 1 line high starting on line 5, 3 columns wide starting in column 18, and the area 1 line high starting on line 9, 3 columns wide starting in column

Commands	Explanation
	18. If the response falls within one of these two areas, it will be recorded with the appropriate identifier (W1 or W2). When a defined wrong answer has been made, the commands from here down to UN (undefined answer) are executed. Then the computer goes back to the EP for this problem. If the response does not fall in one of the defined wrong answer areas, the machine skips from this command down to the UN command.
AD 1/C2	Add: Adds 1 to the defined wrong answer counter (C2).
L3 LD 1/S1	Load: Loads 1 into the error switch (S1).
AUP A03	Audio Play: Plays message #A03. "No."
AUP A04	Audio Play: Plays message #A04. "The word that goes with the picture is 'bag.' Touch and say bag."
DT 7,16/→/	Display Text: Displays "→" on line 7, column 16.
UN	Undefined Wrong Answer: If machine reaches this point in the program, the student has made neither a correct nor a defined wrong answer.
AD 1/C3	Add: Adds 1 to the undefined answer counter (C3).
BR L3	Branches: Branches to command labeled L3. (The same thing should be done for both UN and WA answers. This branch saves repeating the commands from L3 down to UN.)
PR	Prepares the machine for next (2nd) problem.
LD 0/S1 FP F02 DT 5,18/card/	These commands prepare the display for the 2nd problem. Notice the new film position and new words displayed. The student was told to "do the next one" when he

Commands	Explanation
DT 7,18/cart/	finished the last problem so he needs no audio message
DT 9,18/hard/	to begin this.
L4 EP 30/ABCD2	Light-pen is activated.
AD 1/C4	These commands are done only if no response is made in
LD 1/S1	the time limit of 30 seconds. Otherwise the machine
AUP A07	skips to the CA command.
DT 5,16/→/	
BR L4	
CA 1,5,4,18/C2	Compares response with correct answer area.
BR L5/S1/1	1 is added to the initial correct answer counter unless
AD 1/C1	the error switch (S1) shows that an error has been
L5 AUP A05	made for this problem. The student is told he is correct and goes on to the next problem. These commands are executed only if a correct answer has been made.
WA 1,7,4,18/W3	Compare response with defined wrong answer.
WA 1,9,4,18/W4	
AD 1/C2	1 is added to the defined wrong answer area and the
L6 LD 1/S1	error switch (S1) is loaded with 1 to show that an
AUP A06	error has been made on this problem. The student is
AUP A07	told he is wrong and shown the correct answer and asked
DT 5,16/→/	to touch it. These commands are executed only if a defined wrong answer has been made.
UN	An undefined response has been made if the machine reaches this command.
AD 1/C3	1 is added to the undefined answer counter and we branch
BR L6	up to give the same audio, etc. as is given for the defined wrong answer.

Thirty counters that can be used to keep track of a student's performance are available to the lesson programmer. During the instructional flow the current values of these counters are used to make branching decisions regarding what stimulus materials are to be presented next. For example, if the correct-answer counter for a particular class of problems has a high value, the student may be branched ahead to more difficult topics, whereas for a low value he may be branched to remedial work. These counters can contain any number from 0 to 32,767. They are normally set at zero at the beginning of a course and added to when desired. For example, counter 4 (C4) was used to record overtimes; each time the time limit was exceeded one was added to counter 4 (AD 1/C4).

There are also 32 switches available to the instructor. A switch is either in the zero or one position. These are used to keep track of previous events. For example, at the beginning of a problem, zero is loaded into S1 (the "error" switch). This indicates that no error has yet been made on this problem. If the student makes an error on the problem, one is loaded into S1. Then, if a correct answer is made on his second try, the command can be branched around adding one to the initial correct answer counter because the error switch (S1) is equal to one.

There are many features of the CAI system that are not demonstrated by the simplified example presented here. The pattern of the problems may vary widely from this sample. At various points in a lesson, criteria may be set which, if not met, may cause the student to branch to remedial problems or have the proctor called. Parts of the CRT display may be underlined or displayed in synchronization with the audio messages.

While a student is on the system he may complete as many as 12 or 15 problems of the type shown above per minute; providing a significant amount of coded lesson material for student use is a major problem. The typical procedure in the reading program is to present material in blocks such that the problems are alike in format, differing only in certain specified ways. The two example problems differ only in 1) film display, 2) words displayed, 3) problem identifier, 4) the three audio numbers, 5) row display of "$\rightarrow$" (correct answer row), 6) correct answer area, 7) correct answer identifier. This string of code can be defined once, given a two-letter name, and used later by giving a one-line macro command; the specifics which vary from problem to problem are called parameters.

The use of macros cuts down greatly the effort required to present many different but basically similar problems. For example, the two problems which were presented command by command above would be presented in macro format:

Problem 1: CM PW]F01]bat]bag]rat]A01]ABCD1]A04]A02]A03]7]1,7,3,18]C1]

Problem 2: CM PW]F02]card]cart]hard]]ABCD2]A07]A05]A06]5]1,5,4,18]C2]

The command to call a macro is CM and PW is our two-character code for the macro involving a picture-to-word match. Notice that in problem 2 there is no introductory audio message; the "]]" indicates that this parameter is not to be filled in.

The macro capability of the source language has two distinct advantages over code written command by command. The first is ease and speed of coding. The call of one macro is obviously easier than writing the comparable string of code. The second advantage is increase in accuracy. Not only are coding errors drastically curtailed, but if the original macro is defective or needs to be changed, every occurrance of it in the lesson coding can be corrected by modifying the original macro; in general the code can stay as it is. The more standard the problem format the more valuable the macro capability becomes. Apart from a few non-standard instructional audio messages and display items, approximately 90-95% of all the reading curriculum has been programmed using roughly 110 basic macros.

One should note that a full account of all incorrect and correct answers can be gathered in the array of history registers, although this account is only one portion of the current history of a student. There are a sufficient number of these registers so that quite sophisticated schemes of optimization and accompanying branching is possible. Thus, one is in a position to present a series of words and to optimize the number of correct responses to some stipulated criteria, for example, five consecutive correct responses for each of the words. Or one can select from an array of phrases choosing those phrases for presentation that have the greatest number of errors for any particular learner. From these decisions, each individual student can pursue a fundamentally different pathway through the reading materials. The full extent of the flexibility of this decision making capability of the CAI system is still being explored by the Project staff.

Project Design and Testing Program

The Stanford CAI Project is being conducted at the Brentwood School, in the Ravenswood School District (East Palo Alto, California). Criteria used in the selection of the school were:

1) a school with sufficient student population to provide at least 100 first-grade students who could participate in the project,
2) a school whose physical grounds were sufficient to permit the erection of a 30' by 100' building which could become an integral part of the school plan,
3) a school whose student population is predominantly composed of "culturally disadvantaged" children, and
4) a school whose principal and faculty have demonstrated through past performance a willingness to undertake new educational innovations.

The Brentwood School met all of these qualifications, and its students began daily instruction via CAI in the fall of 1966. One-half of the first-grade students take reading via CAI; the other half of the group functions as a control group and are taught reading in the manner employed by the school before the CAI project began (these children are not left out of the project--they take math from the CAI system instead). The students were very quickly "phased in" at the beginning of the year, with a teacher or aide for each student. As new students join (those entering the school as transfers, for example), they are added to the group with such teacher assistance. A teacher or proctor is on hand at all times and has a CRT unit which summons her to students needing help, if she does not spot them herself. All first-grade students were tested extensively, so that we may relate individual outcomes from the reading program to various variables that research suggests may be relevant, in order to understand reading behavior better.

Teacher Inservice

One of the most crucial elements in the testing of an innovation such as CAI is the willingness of the faculty and administration to participate and the experience that they can bring to the project. A system such as the Stanford Project may eventually offer teachers a great deal of assistance, thereby rendering their jobs easier, and such claims have been made for CAI. These claims are justified, if viewed in the light of the potential that CAI has as a tool; as an innovative project in its formative stages, however, CAI has probably made the teacher's job harder, if more rewarding. As we learn, by trial and error, what works and what doesn't in the teaching of reading, the teachers stand by to make sure that all students are learning as much as they can and should. Where a particular unit poses difficulties for an individual student, the teacher must step in with supplementary help (this is particularly true in the case of identifying and helping students who will be classed as having severe reading problems--and each first-grade class has a few). The teacher must know where each student is and what he needs from her--and now her students are progressing at their own speed and no two of them may be at the same place in the material. This situation provides a challenge that our teachers at Brentwood have met, and we are learning a great deal about the coordination of CAI and classroom activities. It would be unfair, however, to "sell" such a project to teachers by promising that it will make their workload less. In its present state, CAI makes the teacher's role different, but no less demanding.

In order to perform successfully in this new role, teachers must be given enough information and help so that they understand the materials and the procedures of the project in some detail. The Stanford Project provides a project coordinator who is at the school full time. Several other staff members are provided, as is the staff for the actual running of the computer system. The Project staff held a series of meetings for faculty and administration at the school. These meetings (in the fall of 1965), covered: 1) introduction and overview of CAI and plans for the project, 2) terminology of CAI and programmed instruction and an overview of the proposed CAI system, 3) the nature of programmed instruction, its objectives and relation to learning theory, 4) an overview and critique of available programmed texts, 5) the sociology of educational change, the function of educators and their interrelation with new technology, and 6) a series of proposed new reading experiments utilizing CAI.

In the spring of 1966, an inservice course for teachers at Brentwood was held. The course gave teachers an opportunity to read in the area of CAI, programmed instruction, and educational innovation, as well as the opportunity to investigate the problems involved in programming and planning for educational innovations and developing reading and mathematics curriculum for CAI. Meetings with teachers and staff have been continued through the year of the project's existence. The initial course offered university credit; further meetings have included non-credit courses, workshops, released-time planning sessions, and informal session with project staff members.

Results and Discussion of the Project

The full analysis of the individual records for each child will consume considerable time, and begin in the late spring of this year. We have some of the results from the first year's post-tests and these will be presented. In addition, we have learned a great many things about the computer system; the workings of a project like this one within an existing school system; and students behavior in the CAI situation.

A report on student progress at a fairly gross level is generated each week, primarily for the information of the teachers. The report contains the individual student's name, the lesson (by level and lesson number) on which the student is working, the number of proctor calls received for that student during the week, and a cumulative weighted index of the student's performance for each of the six major problem blocks. Also included in the report are the cumulative number of sessions that each student has been on the machine, the number of absences of each student during the week and the amount of time off for each student for the week. The last three categories are computed from the teaching proctor records. The remainder of the report is generated by reading off pertinent items from the student record held on the disc. The performance index for each student in each of the six problem blocks is computed in the following manner: A series of six counters are assigned for the computation of the performance index. As a student proceeds through a problem block the counter for that block is indexed to indicate the proportion of initial correct responses made. When the student has completed the block the contents of that register are used to update the associated performance index in the student record. The current value for the register is read out and the new value is added. The updating of the register, however, is done by using a scheme that assigns a weight α to the previous value and a weight $1-\alpha$ to the current value. The value of α has been arbitrarily set at 0.6, but a more optimal value can be determined once data has been analyzed from this year's run.

Although the weekly performance report is prepared primarily for the classroom teacher and the proctors, it provides data sufficient to examine several questions about student performance. The weekly student performance record has been used in the following analyses.

1. Spread on Main Line Problems: There exists within the lesson material a central core of problems which we have termed main line problems. Main line problems are those over which each student must exhibit mastery in one form or another. Main line problems may be branched around by successfully passing certain screening tests or main line problems may be met and successfully solved, or they may be met and through incorrect responses the student is branched to remedial material. The student is always returned to the main line problems. Each lesson contains about 125 main line problems. Therefore, the number of lessons completed by a student may be used as an index of the number of main line problems successfully completed.

The first year of the project ended with a difference between the fastest and slowest student of 6,250 problems completed. The inter-quartile range was 1,875 problems. There was, however, a rather wide variation in the amount of time spent on the system by the students (the numbers reported above are based only on records of students who began the program in November, 1966). In order to take this variation into account, a rate of progress score was computed by dividing the number of problems completed at the end of the year by the number of sessions that the student has had on the system.

The range in rate of progress was between 33.75 problems per hour for the slowest student to 161.25 main line problems for the fastest student. The inter-quartile range is 45.05 to 112.50 with the median at 75 problems per hour.

From the standpoint of both the total number of problems completed during the year and the rate of progress, it is clear that the CAI reading curriculum is accounting for individual differences on at least one dimension (i.e., the movement of the individual student through the lesson material). The differences noted above must not be confused with a variation in rate of response. The difference in the response rate among students was very small. The average rate was approximately four responses per minute. The differences in the total number of main line problems completed and in the rate of progress can be accounted for by the amount of remedial material, the optimization routines, the number of corrections, and the number of accelerations for the different students.

2. Sex Differences. It has been a common finding in reading studies that girls generally excel boys in the acquisition of reading skills and in reading performance, particularly in the primary grades. The suggestion has been made many times that these differences might be attributed, at least in part, to the social organization of the classroom and to the value and reward structures of the predominantly female primary grade teachers. It has also been argued on developmental grounds that first-grade girls have a greater facility in visual memorization than boys of the same age, and that this somewhat greater ability for visual memorization aids the girls in the essentially sight-word method of vocabulary acquisition commonly used in the current basal reading series. If these two arguments are viable, then one would expect that by placing students in an enviornment such as a CAI tutorial system and using a curriculum which emphasizes analytic skills

as opposed to rote memorization of words, such as a linguistically oriented curriculum, that one would remove or at least minimize the sex difference in reading performance. In order to test this notion, the rate of progress scores taken from the final teachers' report were rank ordered and tested for sex effects using a Mann-Whitney U Test. The null hypotheses in this and in the following tests is that the scores for the boys and the scores for the girls have the same distribution, tested against the hypothesis that the scores for the girls are higher than those for the boys. The test of sex effects yielded $z = .053$. Under the null hypothesis the probability of $z \geq .05$ is 0.36. Sex difference then is not an influential variable in the rate of progress in the Stanford CAI reading curriculum.

Sex differences might be a factor in accuracy of performance. To test this notion the final performance index scores for each of the four standard problem types reported on the weekly teachers' report were examined using the Mann-Whitney U Test. The results were as follows:

Letter identification: $\Pr(z \geq 0.33) = 0.37$

Word list: $\Pr(z \geq 1.83) = 0.03$

Sounding matrix: $\Pr(z \geq 1.41) = 0.08$

Sentence comprehension: $\Pr(z \geq 1.37) = 0.09$

The only difference between boys and girls significant at the 0.05 level was found in the word list scores. However, the scores in the matrix and comprehension sections were in the expected direction (i.e., girls excelling boys). These results, while by no means definitive, do lend support to the notion that when students are removed from the normal classroom social milieu and placed in the asocial environment of a CAI tutorial system, boys perform as well as girls in overall rate of progress. The results also suggest that in a CAI environment the sex difference is minimized in proportion to the emphasis on analysis rather than rote memorization in the learning task.

The one problem type where the girls achieved significantly higher scores than the boys was the Word List section which is essentially a paired-associate learning task.

3. Post-Test Results. The reader may recall that the first-graders at the Brentwood School were divided into two groups. Half of them received reading instruction from the CAI system; the other half did not (they received math instruction instead). Both groups were tested extensively before the project began and late this spring. The two groups were not significantly different at pre-test time. Table 2 presents the post-test results for some of the tests that were administered. As inspection of the table will show, the experimental group (those who received reading instruction via CAI) performed significantly better on all of the post-tests except for the comprehension subtest of the California Achievement Test (CAT). These results are most encouraging. It seems clear that reading instruction provided by the Stanford CAI System results in better performance, as measured by these tests, than does the usual classroom instruction. Further, it should be noted that at least some of the effects that might be attributed to the "Hawthorne Phenomenon" are not present here; the "control" group was exposed to CAI experience in their math instruction. While that may leave room for some effects in their reading, it does remove the chief objection, since these students also had reason to feel that special attention was being given to them. It is of interest to note that the average

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Insert Table 2 About Here

Stanford-Binet I.Q. score for these students (both experimental and control) is 89. While considerable variation exists, these are, by and large, not exceptional or gifted children. The program's successes are, we feel, the more valuable for what they may offer to students like those in the project.

Owing to systems and hardware difficulties, the Stanford CAI System was not in full operation until late in November of 1966. Students were given a relatively brief period of time per day on the terminals initially. This period was increased to 20 minutes after the first six weeks; in the last month we allowed students to stay on the terminal 30 to 35 minutes. We wished to find out how well first-grade students would adapt to such long periods of time. They adapt quite will, and next year we plan to use 30-minute periods for all students. This may seem like a long sesson for a first-grader, but our observations suggest that their span of attention is well over a half hour if the instructional sequence is truly responsive to their response inputs. This year's students, however, had a relatively small number of total hours on the system. We hope that by beginning in the early fall and using half-hour periods, we will be able to give each student at least 80 to 90 hours on the terminals next year. The achievements of this year's students are most satisfactory in the light of the limited amount of exposure they had.

Much of the data from this year's run remains to be analyzed. We have just begun to retrieve individual student protocols from the permanent records stored on tape, and will have, hopefully, a detailed analysis of various parts of the curriculum to use in making revisions for next year and to use in evaluating alternative models of the learning process. It is our hope that such analyses will help to lay the ground work for a theory of instruction that will span the diversity of concepts and skills found in an elementary school subject such as reading. From our view, the development of such a theory should be the major goal of a viable psychology of human learning.

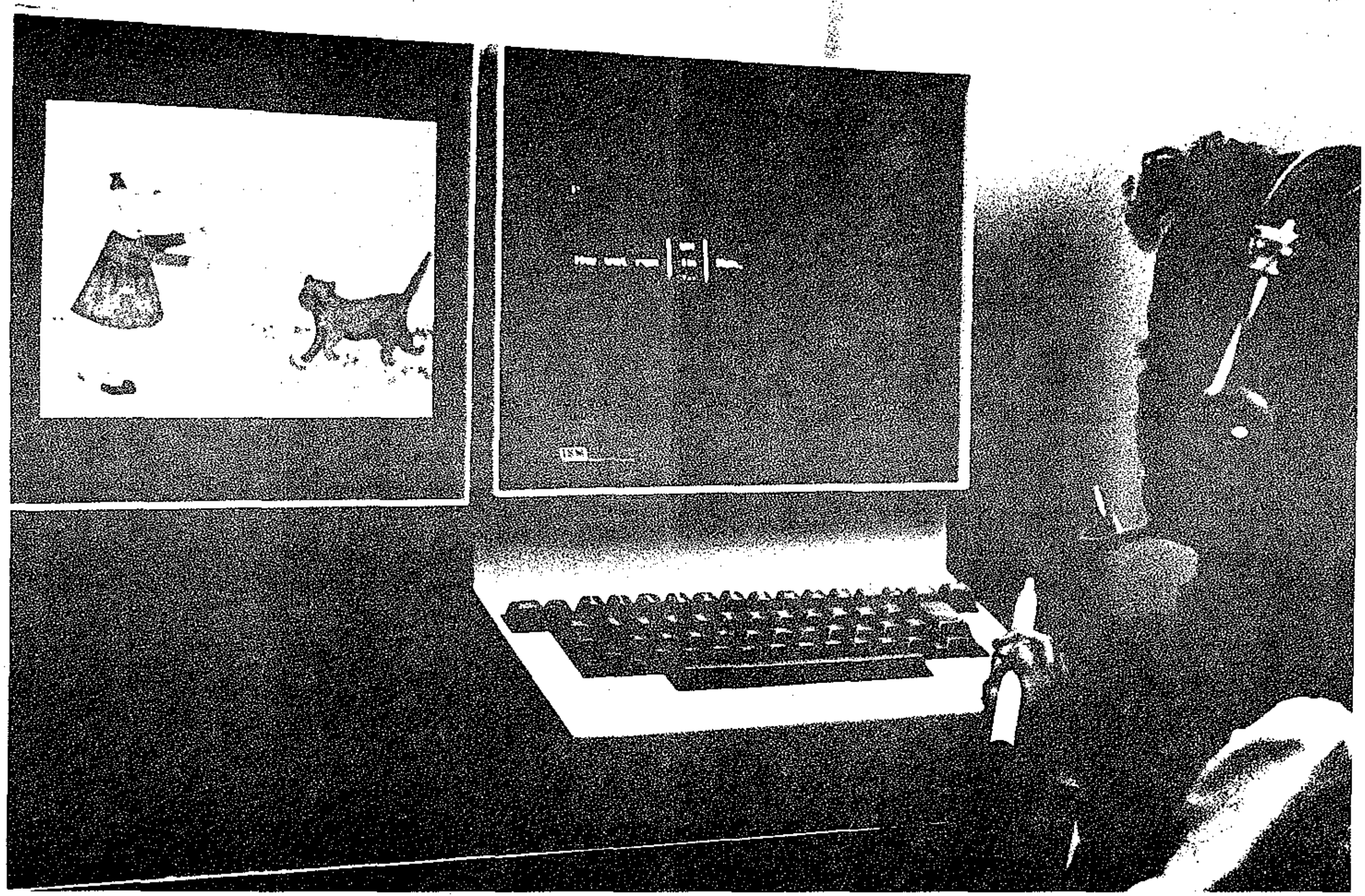

Figure 2. Student terminal for computer-assisted instruction.

FOOTNOTES

1. Support for this research was provided by the United States Office of Education, Grant Nunber OE5-10-050.

2. This system was developed under contract between Stanford University and IBM. Subsequent developments by IBM of the basic system have led to the IBM 1500 Instructional System which is now commercially available.

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Table 2

Mean Values on Post-Tests for Experimental and Control Groups

Test Type	Experimental	Control	p-value
California Achievement Test			
Vocabulary	51.87	42.10	$<.01$
Comprehension	48.20	49.00	----
Total	51.14	43.55	$<.01$
Hartley Reading Test			
Form Class	11.22	9.00	$<.05$
Vocabulary	19.38	17.05	$<.01$
Phonetic Discrimination	30.88	25.15	$<.01$
Pronunciation			
Nonsense Word	6.03	2.30	$<.01$
Word	9.95	5.95	$<.01$
Recognition			
Nonsense Word	18.43	15.25	$<.01$
Word	19.61	16.60	$<.01$