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ABSTRACT

Detailed is the instructional design of a computer assisted instructional (CAI) program to teach deaf students how to use a ruler. Fourteen instructional objectives are listed, and task analysis information is presented. Diagrams and illustrations are used to portray the general instructional strategy used in the program. Results of program implementation and field testing are said to indicate that the CAI program taught the intended final objective in a relatively short period of time in addition to two more general learning skills: the importance of reading and following instructions, and the need to be precise in pointing responses. (CL)

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A CAI program to teach deaf children how to use a ruler: A study in instructional design

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A CAI Program to Teach Deaf Children How to Use a Ruler: A Study in Instructional Design

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A very strong case can be made for the use of Computer Assisted Instruction (CAI) with students who have learning disabilities due to deafness, blindness, physical handicaps or emotional disturbances. One good reason is that CAI allows individualized instruction. Thus, students can progress at their own rate and not be frustrated by instruction which is either too easy or too difficult for them. Furthermore, a CAI program can deliver instruction which is adapted to the particular abilities/aptitudes of the student. In the case of the learning disabled, this is particularly crucial. While a normal student can compensate for the lack of one ability by means of another, disabled students are usually limited in their range of abilities. Thus individualized instruction which capitalizes upon their strengths and compensates for their weaknesses is much more likely to result in successful learning.

A second important feature of CAI is its interactive nature. Because a student must continously respond to questions and hence actively participate in the instruction, interest, motivation, and attention are maintained. Furthermore, immediate feedback and reinforcement not only maintain interest but they also ensure that the student will discover what is correct and incorrect. If proper shaping is used in conjunction with positive feedback, the student can very quickly build up confidence in the task. Since students with disabilities often have low self-esteem or lack self-confidence, this is very important.

The capability to individualize instruction and provide immediate feedback encourages the student to learn. In addition, CAI programs are typically very carefully designed and then systematically tested and refined. Furthermore, because CAI can provide a sophisticated (and unobtrusive) monitoring of student performance, the teacher is able to follow the progress of the student to a much finer degree than is possible in any conventional classroom setting. All of these factors taken together mean that CAI can provide very effective instruction. In the case of the learning disabled, effective instruction is a must for they simply cannot afford the consequences of poor instruction.

Because of the amount of work which is involved in

1. We would like to acknowledge the help of David Baine, Department of Educational Psychology, University of Alberta for his help in the task analysis stage of the project.

producing CAI programs, their development costs tend to be high. However, such development costs can be distributed across the number of students and years which a program can be used. More importantly, the actual operating costs, relative to the high costs of specially trained teachers, are quite favorable. Thus, while CAI is still too expensive to use in regular classrooms[2], in the case of special education, the costs are actually often less than conventional means (see for example, Jamison, Suppes & Butler, 1970).

Despite these compelling facts, CAI has not been extensively used to date with disabled students.[3] An exception to this is the large-scale Stanford University project for hearing disabled students. The project centered mainly around schools for the deaf in Texas but also included schools in California, Florida, Maryland, and Washington, D.C. Curriculum focused upon elementary mathematics and language arts although other subjects (e.g., logic, programming) were tried out. Thousands of deaf students of all ages recieved CAI instruction. Not only did they generally prefer CAI over conventional methods, but well designed studies showed impressive gain scores due to the programs. In addition, the evaluation data strongly showed that the cognitive performance of deaf children was as good as normal-hearing children when tasks did not directly involve verbal skills. A good overview of the Stanford project is given by Fletcher & Suppes (1976).

The present report describes a CAI program designed to teach deaf students how to use a ruler. The focus of the discussion is upon the instructional design of the program. This includes the details of the task analysis, the instructional strategies, and the stages in the implementation and evaluation of the program. It is hoped that this discussion will help to illustrate the sophistication which can be achieved using CAI and convey the potential that it has for the education of disabled students.

Task Analysis

The overall goal of the program is to teach students how to use a ruler as a necessary skill required in drafting and graphic arts. The program was intended for use with students in a vocational programme. The specific terminal objective for the

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2. This situation is changing rapidly as the costs of computer hardware and telecommunications continue to drop dramatically each year. Thus, it is very likely that computers in the classrooms will be commonplace in the next decade.
3. Cost is certainly a major factor here but an equally important obstacle is the lack of awareness on the the part of those involved in special education about the capabilities and potential of CAI for teaching the disabled.

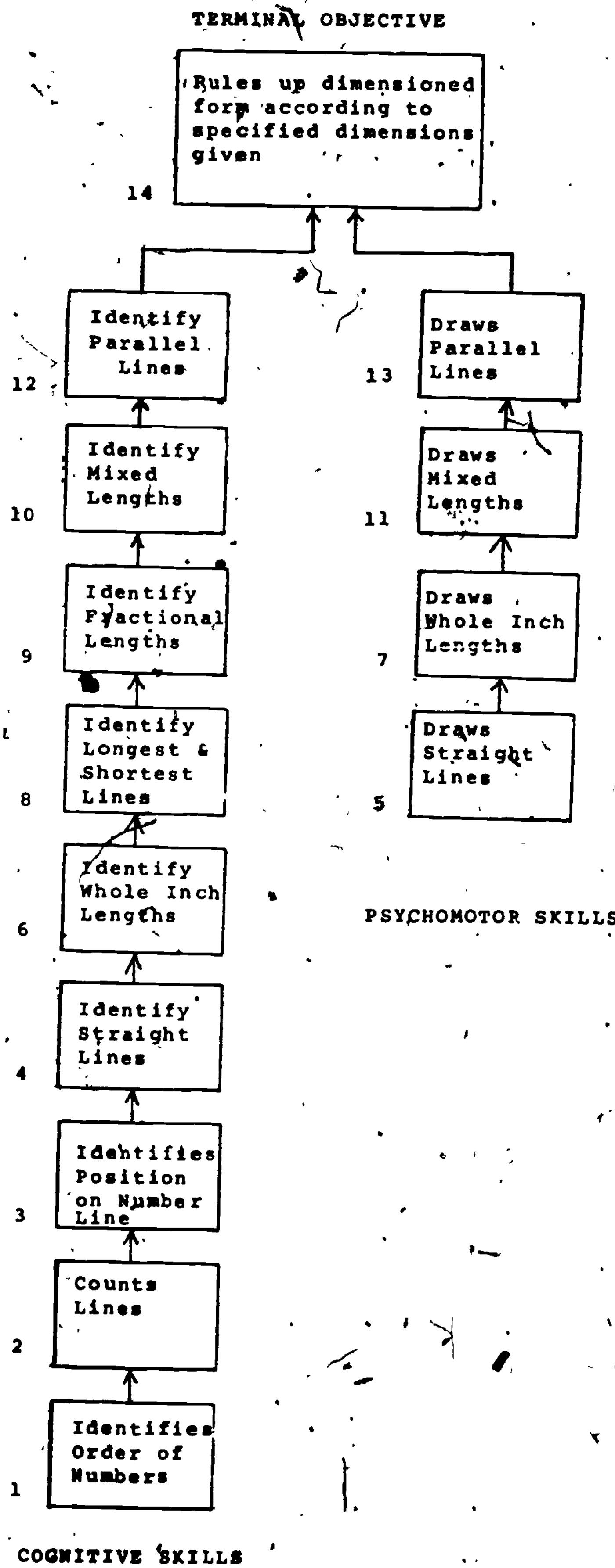
TERMINAL OBJECTIVE
Rules up dimensioned form according to specified dimensions given
14
Identify Parallel Lines
12
Draws Parallel Lines
13
Identify Mixed Lengths
10
Draws Mixed Lengths
11
Identify Fractional Lengths
9
Draws Whole Inch Lengths
7
Identify Longest & Shortest Lines
8
Draws Straight Lines
5
Identify Whole Inch Lengths
6
PSYCHOMOTOR SKILLS
Identify Straight Lines
4
Identifies Position on Number Line
3
Counts Lines
2
Identifies Order of Numbers
1
COGNITIVE SKILLS

Figure 1.

TABLE 1

Instructional Objectives.

CONDITIONS	PERFORMANCE	CRITERIA
1. Given a series of dots numbered from 0 to 16 on the screen	Using light pen, points to the dots in successive order	Each dot constitutes one trial. No more than 3 errors for all 16 trials
2. Given a series of vertical bars in sets of 1 to 16 on the screen	Counts the number of bars and types in the answer	4/5 Correct
3. Given the numbers from 0 to 16 in random order and a linear scale with 12 equally spaced numbered intervals on the screen	Using the lightpen, points to the correct position on the numbered scale	10/13 Correct
4. Shown a series of straight and curved lines in pairs with the discrimination becoming more difficult for each pair	Using the lightpen, points to the straight line in each pair	4/5 Correct
5. Given illustrations of the correct way to hold and position the ruler, pencil, and paper, and using a pencil and ruler	Draws straight lines between indicated crosses (x) on paper	7/8 Correct
6. Given display of standard ruler on the screen	Using lightpen, points to the whole inch marks	4/5 Correct
7. Given instruction on the screen about how to draw measured line lengths and pencil and ruler	Draws lines of whole inch lengths always starting at the 0 mark	4/5 Correct
8. Given a series of line segments of different lengths on the screen	Using lightpen, points to the shortest and longest line segments	2/2 Correct
9. Given instruction on finding 1/2, 1/4, 1/8 and 1/16 marks on ruler and enlarged 1 inch portion of ruler on screen	Using lightpen, points to all fractional marks	100% mastery. Must be with 1/16"
10. Given instruction about combining whole and fractional marks and display of full ruler	Using lightpen, points to correct mark	4/5 Correct
11. Given ruler and pencil and directions on screen	Draws lines of mixed fractional lengths	13/16 trials correct with 1/16" accuracy
12. Given a series of parallel and non-parallel lines in pairs and instructions on the screen	Indicates (by typing yes or no) whether pairs of lines are parallel	4/5 Correct
13. Given instruction on how to draw parallel lines via illustrations and pencil, ruler and paper	Draws parallel lines a specified distance apart	3/4 Correct with 1/16" accuracy
14. Given instructions on the screen, a dimensioned sketch, and pencil, paper, and ruler	Draws a dimensioned form according to specifications	Each line is 1 trial. Form consists of 8 lines 7/8 trials correct with 1/16" accuracy

program was that the students would be able to rule up a dimensioned form according to given specifications.

The major objectives in the program are shown in Figure 1. As the Figure shows, the program involves the blending of a set of cognitive skills with psychomotor skills. The cognitive skills involve the discrimination of line lengths, relative spatial positions of the marks on the ruler, learning the concepts of straight and parallel lines, and the rules associated with learning which fractions correspond to which specific marks. Thus, in terms of a taxonomic analysis, the cognitive components involve the skills of discrimination, concepts, and rules. The psychomotor skills required are those involved in holding the ruler and pencil, drawing straight lines, and drawing lines an exact length.

A detailed description of the task objectives in the sequence taught is given in Table 1. The first objective was designed as a connect-the-dot game. The student was presented with an array of numbered dots and instructed to point to the dots in the correct sequential order (see Figure 2). This served to determine that the student could count from 0 to 16 in order and also had the necessary manual dexterity to hold and use a pencil accurately. The game format created a high level of interest and motivation towards the program.

The second objective involved the presentation of varying numbers of vertical bars that the student was requested to count. This established that the student would be able to count the number of marks which denoted a particular fractional unit (e.g., 3/4, 9/16, etc.). The shaping in this objective involved presenting the bars wide apart to begin with and gradually making then closer together so that the final discrimination matched the actual discrimination required on a ruler. The third objective involved presenting the student with a number line with 0 to 12 marked on it and asking the student to identify the position of all the numbers (in a random order). The purpose of this exercise was to shape the student up to recognizing the whole units on the ruler without the complications of the fractional units.

The next objective involved learning to distinquish between a straight and non-straight line. The shaping here involved starting with a discrimination between very curved or wobbly lines and progressing to a finer discrimination between almost straight (but not quite) lines. Having mastered the concept of a straight line, the student was then asked to draw some straight lines. The next objective presented the student with a ruler and asked for the identification of all the unit marks on the ruler (in a random order). After mastering this, the student was then asked to draw lines of various unit lengths and hence combine the skills mastered in the previous objectives.

The next objective presents the student with a number of

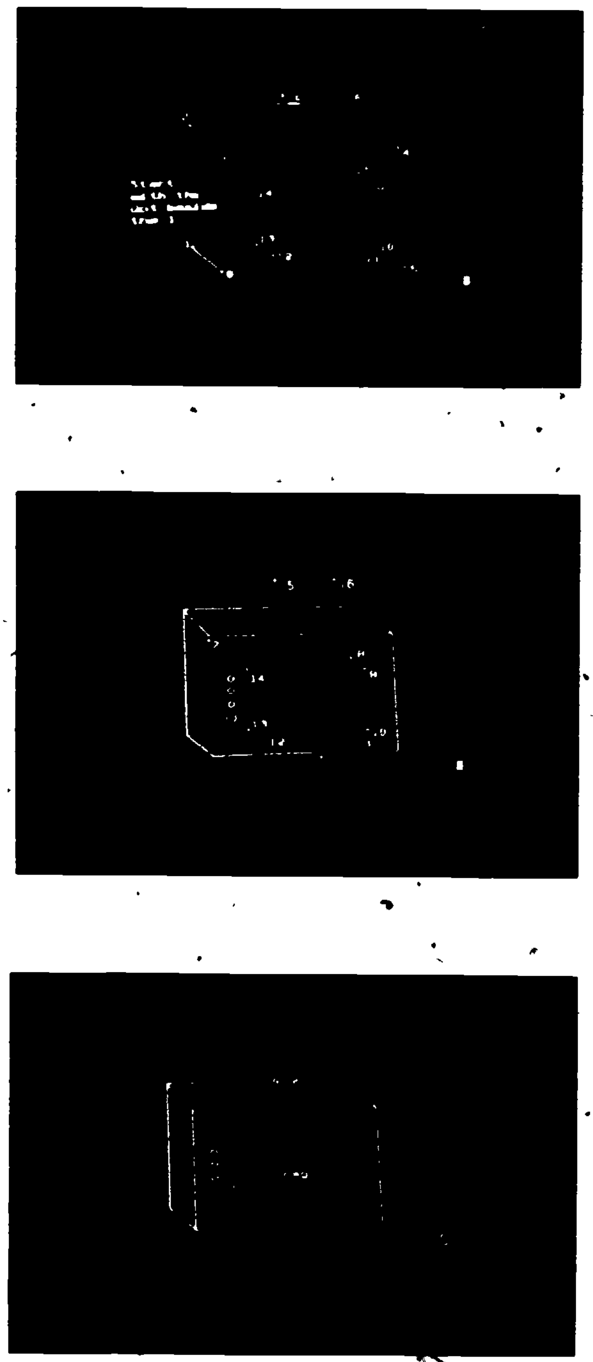

Figure 2. Screen displays from sequence for objective 1.

line segments of different lengths and asks the student to identify the longest and shortest lines. This is a necessary skill in order to be able to distinquish the different fractional marks from each other. The next objective is to actually teach all of the fractional marks in an inch. The instructional strategy used for this is described in detail in the next section. Having mastered the identification of fractional units, the next objective involved having the student draw lines of mixed (unit and fractional) lengths using the ruler.

The next objective involved teaching the student the concept of parallel lines followed by drawing various sets of parallel lines. This step is necessary in order to build the subskill for the final objective which involves drawing up a dimensioned form (consisting of many parallel columns and rows) according to specified dimensions.

The program was designed so that each objective must be mastered before the next objective could be undertaken. The criterion was generally 80% correct except for the objective dealing with the fractional marks in which 100% mastery was required. The reasoning for the setting of these criterion levels was that in a typical test of 5 questions, it is reasonable to expect the student to make one mistake due to carelessness but that 2 or more errors may indicate lack of comprehension or complete learning. The 100% standard for the fractional units was set because this subskill must be pefected to accurately use a ruler. The criteria for the psychomotor objectives involved drawing lines that were straight and within 1/16" accuracy.

With respect to the performance component of the objectives, for most of the cognitive objectives, identification of the correct answer was felt to be appropriate. Thus, being able to identify the correct position on the ruler is the actual nature of the skill required for the task and other response modes (telling, writing, etc.) were inappropriate. Obviously, the most appropriate behavior for the psychomotor objectives was drawing.

The pre-entry skills required are determined by the particular strategy which was adopted (described in the next section). The two critical pre-entry skills required were:

1. the ability to rationally count from 0 to 16
2. the ability to distinguish line lengths

In addition, it was also assumed that students would be able to read at Grade 2 level or above and be physically coordinated enough to hold and use a pencil, ruler and the computer terminal keyboard/lightpen.

Instructional Logic & Strategies

In analyzing the task, an attempt was made to restrict the objectives to only those which were absolutely necessary to achieve the specified terminal objective. Furthermore, in order to minimize the learning demands of the task, a strategy was sought which would involve the simplest types of learning possible. With this in mind, it was decided to use a strategy which would not require the learning of fractions or an understanding of spatial distance. The strategy reflected in the task analysis just described involves learning how to use a ruler on the basis of the length and position of the marks. Thus, the student is taught to associate the denominator of a fractional unit with the length or size of the appropriate mark and the numerator with the position of the mark from the nearest whole inch mark. Using this strategy, the basic cognitive skills needed are the ability to discriminate line lengths and the ability to count -- both of which were considered to be pre-entry skills of the students. This instructional tactic means that it is not necessary to teach the student fractions or spatial partitioning of area which are higher order concepts and principles.

Following this strategy, the student is first introduced to the sixteenth marks and is taught to count every mark starting with the 1/16 mark in order to find the correct 16th mark. Thus, to find the 9/16 mark, the student is told to count 9 marks from the first 16th mark. To find 8th marks, the student must learn to count all the marks as long as or longer than the 8th marks. So to find the 5/8 mark, it is necessary to count the 1/8, 1/4, 3/8, 1/2, and 5/8 marks and none of the 16th marks. The 1/4 and 1/2 marks were also taught this way (although they can simply be memorized). Some screen displays for teaching the 1/8th mark using the counting strategy are shown in Figure 3.

Because there was some doubt that this strategy would work, a complete sequence for teaching the fractional units on the basis of spatial proportions was programmed as remedial instruction. This sequence would be given if the student failed criterion on the final post-test for the objective on fractional units and also had failed criterion on the post-tests for each individual unit. It involved showing a rectangle partitioned into parts and associating the fractions with the appropriate number of parts shaded in. Following this, the enlarged inch was shown (same size as the rectangle) and the fractional marks shown to divide the inch into the appropriate number of parts. Screen displays illustrating this strategy for the 1/8th marks are shown in Figure 4. In contrast to the first strategy described above which started with the 1/16 mark and worked up to the 1/2 mark, this strategy started with the 1/2 mark (dividing the inch into 2 parts) and progressed to the 1/16 mark. Although both strategies started with the simplest unit, this was different depending upon whether the strategy involved the "counting" strategy or the "spatial" strategy.

The general instructional logic used in the program is depicted in Figure 5. At the beginning of each objective to be

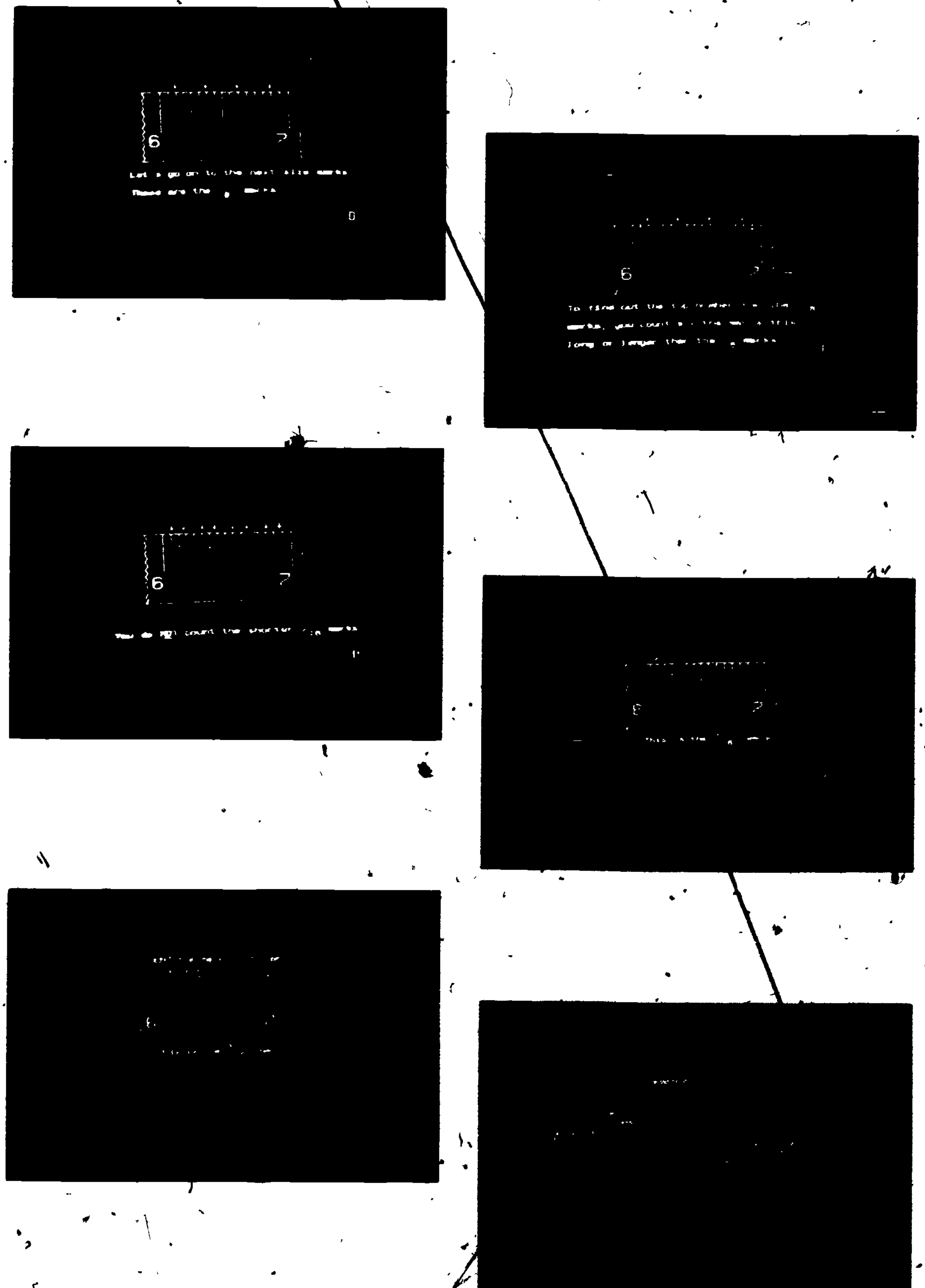

Figure 3. Screen displays for teaching the 1/8 mark using the counting strategy.

Figure 4. Screen displays for teaching the 1/8 mark using the spatial strategy.

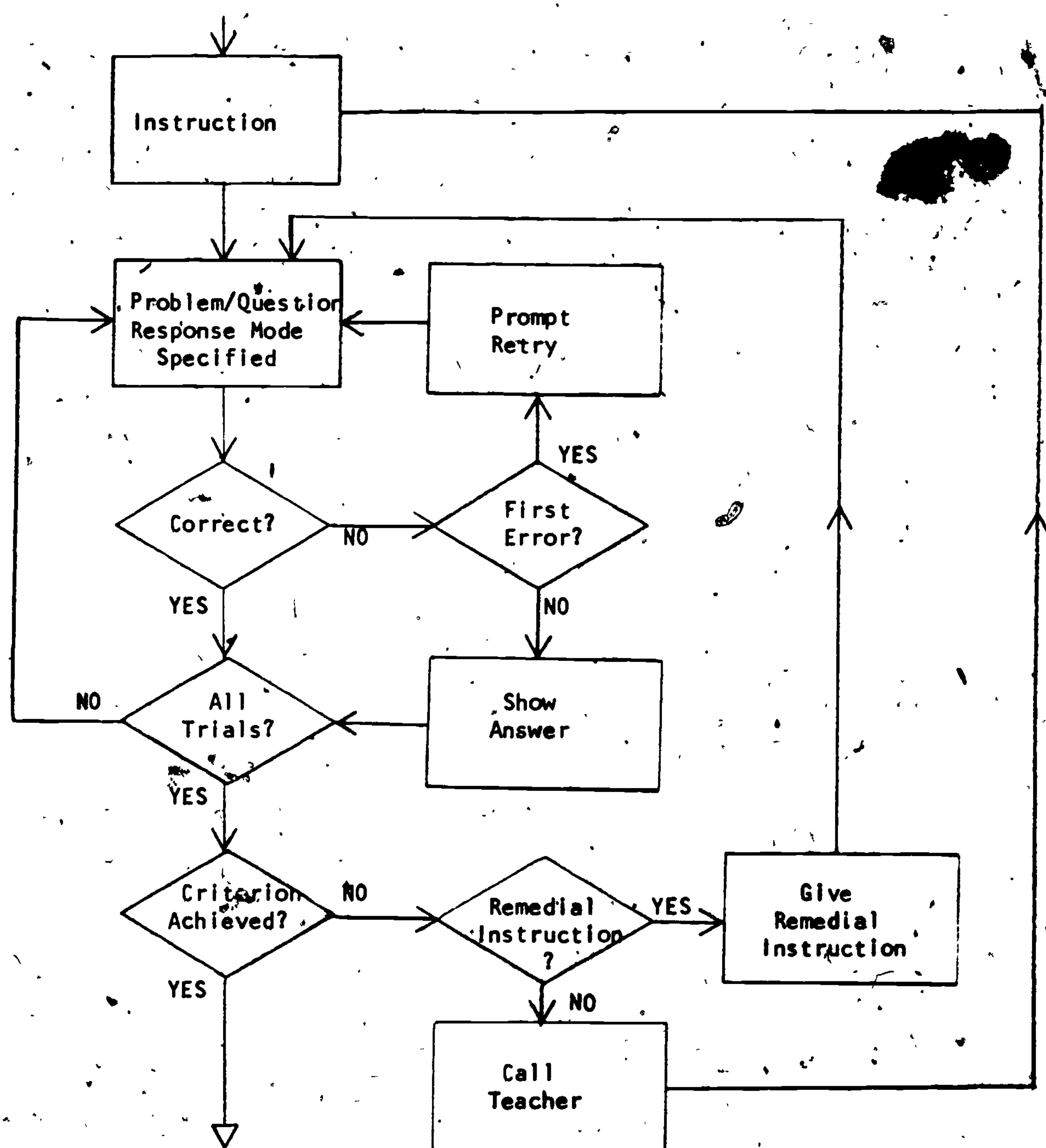

FIGURE 5. General Instructional Strategy Used in Program.

taught, instruction is presented which explains, demonstrates or illustrates the particular skill or concept involved. A post-test follows the instruction which involves the presentation of a problem/question and an indication of the desired mode of response (e.g., typing an answer via the keyboard, pointing with the lightpen, or drawing using a ruler and pencil). The student's response is then evaluated. If the response is correct, a positive feedback message will be given and another question is provided. When the student makes an initial mistake, he/she is prompted for a second try. If the next response is still wrong, an error is recorded and the correct answer is indicated to the student. When all of the available questions/problems have been presented, a test is made to see if the student has achieved the criterion for that objective. If it is met, the student goes on to the next objective. If the criterion is not achieved, remedial instruction is provided if available for that objective or the teacher is called for assistance. Thus the major role of the teacher in this program is not the delivery of instruction but rather the task of diagnosing student problems and providing remedial assistance on an individual basis.

The teaching logic for a specific objective is illustrated in Figure 6. This objective (10) requires the student to identify mixed (whole and fractional) units on the ruler. The student has previously mastered identification of whole and fractional units separately and now must combine these two skills. The instruction for this objective involves showing that the same set of fractional units is found between each set of inch marks (i.e., every inch is divided into the same fractional subdivisions), and that the whole number in a mixed length indicates the inch mark in which a particular fractional unit is found (see Figure 7). This particular point is demonstrated by pointing out different lengths on the ruler with the same fractional unit (e.g., 5 1/2, 7 1/2, 11 1/2). The student is then asked to point to a specified mark on the displayed ruler. If the student points to the correct position (within 1/16 inch), a positive feedback message will be given and another question presented. If the student points to an incorrect position, he/she is initially told to try again, and if the next response is incorrect, the correct position is shown. When five questions have been presented, a test is made to see if the 80% mastery criterion was achieved (4/5 questions correct). If it was, the student goes on to the next objective otherwise teacher assistance is called for and the entire objective is repeated with the teacher present to diagnose and correct misunderstandings. If a remedial sequence was available for this objective, it would have been presented instead of calling for the teacher.

In addition to the general instructional logic outlined, a number of other features were used in the program. In general the teaching of concepts (e.g., straight or parallel line) used the logic of presenting positive and negative instances and

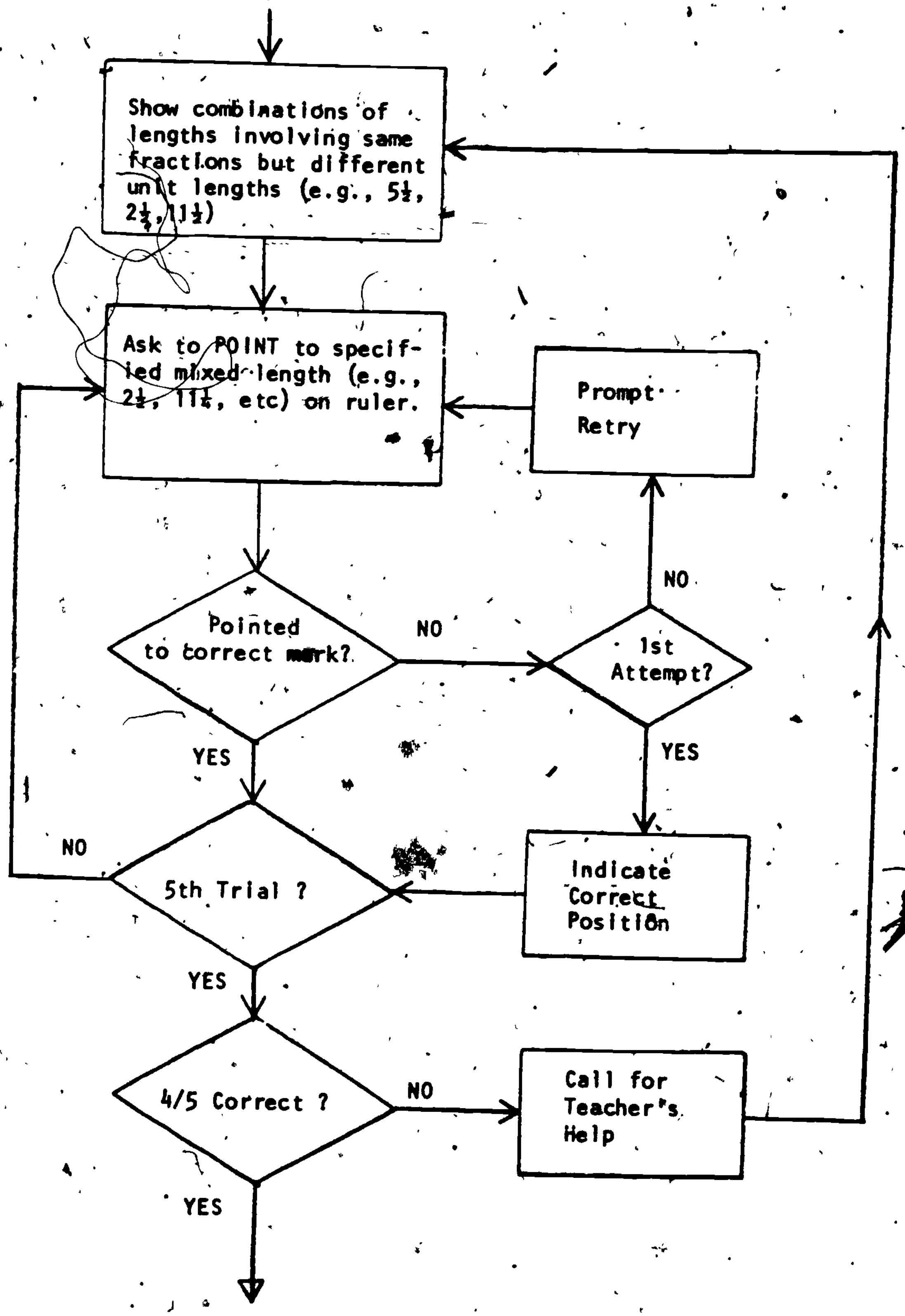

FIGURE 6. Instructional Strategy for a Specific Objective.

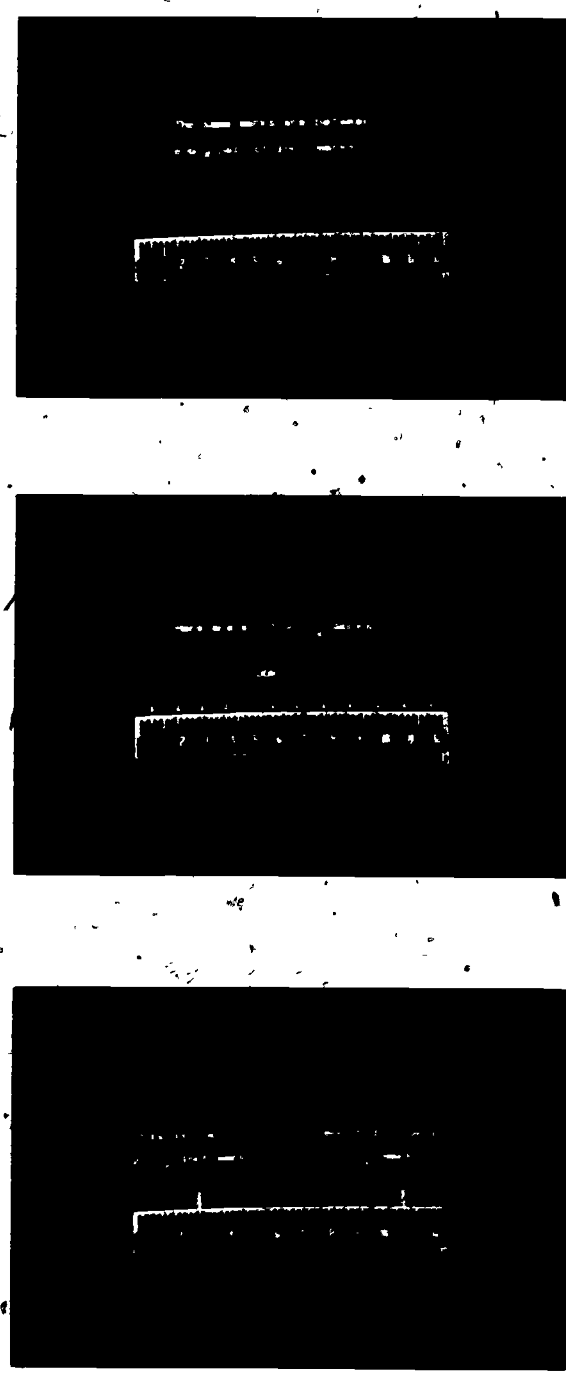

Figure 7. Screen displays from sequence for objective 10.

emphasizing the discriminating/irrelevant attributes. Directional arrows were used throughout the program as attentional cues or prompts to direct attention to aspects of the ruler or the position of marks. All student response was prompted via capital letters (e.g., TYPE or POINT).

The rate of progress through the program is set by the student as he/she controls the presentation of each successive screen display via the space bar on the keyboard. The sequence of presentation follows the organization of objectives given in Table 1 although a branching feature allowed the teacher to manually override the default sequence in order to skip an objective or review an earlier one.

Implementing & Testing the Program

The program was written in COURSEWRITER II and implemented on the IBM 1500 Instructional System operated by the Division of Educational Research Services at the University of Alberta. The 1500 system has 20 student terminals each consisting of a keyboard and CRT (Cathode Ray Tube) screen, an image projector, and an audio unit. Each terminal also is equipped with a lightpen which allows the student to respond to questions by pointing to things on the CRT screen.[4]

Figure 8. Deaf student at a terminal.

4. The details of the system are described in Hunka & Romaniuk (1974).

In writing the program, a number of instructional design considerations were taken into account. Any sequence which could be conveyed via an illustration or animation was done visually rather than verbally. Thus the program as a whole was highly visual to capitalize on the capabilities of deaf students. Screen displays were kept as simple as possible, usually with only one idea being expressed in each display. A great deal of effort was expended to use the most elementary level of vocabulary and simplest sentence construction possible in the verbal material. In particular, slang terms and phrases were avoided. The use of arrows as attentional cues or prompts was mentioned in the previous section. These arrows were mainly used to point out the positions of marks on the ruler, but also to draw the students' attention to important features or changes in the instruction. In addition, techniques such as enlargement, flashing, underlining, and delayed or paused display were employed occasionally. The feedback messages were stereotyped (usually either "right" or "wrong") rather than the usual varied type of feedback messages used with normal students. Almost all responses required in the program were done via pointing to something with the lightpen (rather than typing in answers via the keyboard). This is a simpler response mode and also was appropriate for the type of learning specified in the task analysis.

The initial versions of the program were tested by two different groups: 8 deaf students aged 11-13 at a junior level, and 6 Grade 2 students with normal hearing, aged 7-8. Six of the 8 deaf students completed the program with completion times ranging from 2 hours, 35 minutes to five hours. None of the normal children completed the program. Although they were able to read and understand the instructions, they were unable to master the fractional units. While they could understand each fractional unit by itself, they could not remember two or more together. Thus, it was concluded that the reasoning skills demanded by the program were beyond the typical ability of normal children at this age.

A number of changes were made to the program on the basis of the performance of these two groups. A standard terminal introduction was too complicated for the deaf students and a much simpler version was written. The instruction on fractional units was modified so that the post-test for each unit would review all of the previous units not just the most immediate one taught. Thus, the test for the 1/8 marks also included the 1/16 marks and the test for the 1/4 marks included the 1/8 and 1/16 marks. Originally, only the final post-test for the entire unit had tested all of the marks at the same time. This modification reflected a gap in the original task analysis, namely, the skill of integrating or synthesizing each new fractional unit with the preceding units. In fact, the results suggested that this was one of the crucial subskills in the entire task as indicated by the failure of the normal children to get beyond this step.

Another change to the fractional units involved the inclusion of a "count with me" prompt when the student failed to pick the correct mark in the counting strategy. This involved displaying the message "Count the marks with me" and then pointing to each of the successive marks while also showing the numbers. This demonstrated the correct use of the counting strategy and allowed them to figure out what they had done wrong. Originally, an arrow would have pointed to the correct mark and they would have been told that their selection was "Wrong". The original correction procedure showed them the right answer but did not help them discover what they had done incorrectly.

The last objective was also modified. It was clear that the step size from the objective of drawing parallel lines and that of drawing up a dimensioned form was too large. Instead of asking the students to immediately draw up a page-size dimensioned form, they were asked to draw a series of dimensioned forms beginning with a simple box and working up to more complicated forms. Thus, more shaping was necessary in order to achieve the final objective. In addition, it was necessary to point out to the students that the final dimensioned form would occupy the entire page. This was a minor (but important) aspect which had been overlooked in the original task analysis.

In addition to the changes to the instructional content, a major change was made to the instructional logic. According to the original logic, if a student failed a post-test criterion for an objective, a message was displayed on the screen telling the student to call for the teacher's help. The teacher would watch as the student went through the post-test again and diagnose the problem. It was felt that a single time through each unit provided insufficient practice and also necessitated an excessive demand for teacher assistance. In view of this, the logic was changed so that when a student failed a post-test, they would be branched back to the beginning of the post-test again. If the student failed the post-test on the third attempt, then the message was displayed and teacher assistance called for. The general effect of this change was to increase the amount of drill and practice the student received in the program.

With respect to instructional strategies, it was found that most students had considerable difficulty understanding the counting strategy when it came to the 1/8 marks and they had to learn the rule to count all the marks as long as or longer than the 1/8 marks (but not the shorter marks). Using this rule apparently demanded considerable reasoning ability and hence made the counting strategy much more difficult than we had expected (since it only involved the subskills of counting and discriminating line size). The introduction of this rule was amplified and the student was asked to identify all the lines which were as long as or longer than the 1/8 marks. Although these modifications made the rule easier to learn we were now uncertain that the counting strategy was easier to learn than the spatial strategy. In order to check this, it was decided to empirically compare the two strategies in the test of the program with the target students.

A further problem which emerged in the test runs was related to the use of the light pen. It was observed that many of the errors made by students were due to improper use of the pen. This included holding it at an angle (and hence pointing to something other than intended) or pushing it in when the system wasn't ready to accept input. This could be very frustrating to the students because they would be sure that they were correct but get a "Wrong" message. A number of things were done to reduce this problem. Considerable emphasis was placed in the introduction and in error messages about holding the pen very straight when pointing. Emphasis was also placed upon waiting until the lightpen indicator (a small square in the corner of the screen) was shown before pushing on the pen. Some students had trouble seeing where they pointed the pen because it was at their eye level and hence blocked their field of vision. To correct this, the chairs were raised as high as they would go so that the students would be high enough to look down on their hand as they pointed. Unfortunately, most of the displays requiring pointing were located at the top of the screen rather than at the bottom (a difference of about 5-6 inches) and the movement of these displays would have amounted to almost rewriting the entire program. This problem with height is a good example of the type of unexpected problems which can be encountered which effect the instructional design yet have nothing to do with the content or task.

Field Testing of the Program

When these modifications were completed, the program was then tried out with the intended student group: 15 deaf students (aged 12-15) from a vocational programme. Of these 15 students, 12 completed the program in the period of 3 sessions one week apart. The other 3 students were in the last few objectives and likely would have completed the program given another session. The exact completion times as well as the total number of correct responses are given in the first 2 colums of Table 2. The range is from 1 hour, 23 minutes to 3 hours, 58 minutes with a mean completion time of 2 hours, 23 minutes (for the 12 students who finished). The number of correct responses ranged from 104 to 294 reflecting the number of repetitions or remedial instruction involved. The remaining columns in the Table give the number of responses (correct or incorrect) made in each cognitive objective to achieve the criterion. This does not include responses to questions used in the actual instruction (for prompting or shaping purposes).

One important thing to notice is that while some students were consistently lower or higher in the number of responses

TABLE 2

Summary of Student Performance Data.

Student	Total Completion Time	Total Correct Responses	Total Responses/Objective 1	2	3	4	6	8	9	10	12
1	2:08	131	20	8	14	5	6	2	78	18	15
2	3:58	272	50	6	14	5	5	2	276	5	8
3	1:34	105	17	7	14	20	5	2	28	5	5
4	3:38	243	16	9	13	6	5	2	171	30	8
5	3:58	294	17	5	14	5	5	2	254	23	30
6	1:38	120	16	10	13	12	5	6	40	5	14
7	1:46	103	16	8	13	7	5	2	25	5	6
8	2:40	146	30	7	13	5	5	2	85	38	13
9	3:19(n.c)	135	31	5	14	5	5	2	92	7	14
10	2:06	114	16	7	13	12	5	2	55	12	5
11	1:23	104	27	7	15	6	5	2	25	5	7
12	1:43	106	25	8	14	5	6	2	42	13	11
13	2:14	148	31	5	14	5	7	2	68	66	15
14	2:30(n.c)	140	18	5	14	5	6	2	106	14	11

n.c. indicates course not completed

needed to reach a criterion, there were certain objectives which gave some students trouble but not others (e.g., student 3 and objective 4, student 11 and objective 1, students 8 & 13 and objective 10, etc.). This suggests that students differ in their specific competencies on the subskills involved in the task and hence qualitative analysis and evaluation on each skill is necessary. This data also shows that some subskills were relatively easy for all students (e.g., objectives 2,3,6,8) while others involved considerable individual variance (e.g., objectives 1,9,10,12). This suggests that certain subskills were pre-entry skills possessed by most or all students at this level (and possibly could be eliminated from the program) while others were skills not mastered by some of the students (and hence required in the program).

In order to evaluate the relative effectiveness of the instructional strategies for teaching the fractional units, half of the students were randomly assigned to the counting strategy (students 1-7) and the other half to the spatial strategy (students 8-14). Both groups of students received identical instruction in units 1 through 6. Furthermore, both groups received exactly the same post-tests for each fractional unit (although they were in opposite order for the two strategies) and the same post-test on the overall objective. If a student failed the unit tests and the final post-test using one strategy, the alternative strategy was tried.

As the data in Table 2 shows, the 7 students in the counting strategy made more errors in general than the 7 students who got the spatial strategy even though the number of errors in the first 6 objectives were about the same for the two groups. In fact, there was no significant difference between the mean scores of the two groups for the first 6 objectives, but the means of the two groups on objective 9 (fractional units) were significantly different ($t=2.71$; $p<.05$, 2-tailed). These results appear to suggest that the spatial strategy is better, although at least three of the students (3,6,7) who had the counting strategy did quite well. Furthermore, it should be noted that the sample sizes are quite small and may be affected by violations of assumptions (e.g., homogeneity of variance) of the t statistic. However, it seems reasonable on the basis of these preliminary results to use the spatial rather than counting strategy as the main strategy.

The performance data from this pilot test indicate that the program provides efficient instruction. However, there are some further modifications which are desirable. One of these involves putting the photographic instruction for the psychomotor objectives under computer control. This involves displaying the photographs as slides on the 1500 image projector and displaying corresponding instructions on the CRT screen. This will make the psychomotor instruction interactive and allow monitoring of performance on these objectives as well as the cognitive objectives. However, the evaluation of the psychomotor objectives must still be done by the teacher since there is no way to make this kind of evaluation on the CRT due to screen curvature and the limited resolution of the lightpen (about 1/8 inch). Other improvements will involve the use of a game strategy (as used in the first objective) in other parts of the program to increase attention and interest. Further use of animated sequences would also help with attention and interest. Finally, the use of color (not available on the 1500 system but available on other CAI systems) would increase the motivation of the students and also be helpful instructionally (e.g., cueing).

In addition to teaching the students the intended final objective in a reasonably short amount of time, the program seems to have taught two more more general learning skills to these students. The first of these is the necessity of reading and following instructions. Students initially did not read the instructions carefully (or at all) and would try to guess what they were required to do. When they did this, they would be unable to achieve the criterion and would be returned to the beginning of the unit again. They quickly learned that they could avoid this repetition if they read the instructions the first time and followed them exactly. The second and related skill learned was the need to be precise in their pointing responses. Thus, if they did not point to the correct position on the ruler, they were told to try again and be more careful in pointing. They soon learned to be very accurate in their pointing responses. This accuracy carried over to the psychomotor objectives which was highly appropriate since this was demanded by the criterion. While it is unknown whether these two learned skills transfered to other subjects or tasks the students learned, it certainly seems that these were important by-products of the program and using CAI. Thus, a greater diet of CAI programs might not only improve the specific skills they are designed for but contribute to a greater general learning ability.

Conclusions

The preceding discussion has described the instructional design aspects of a CAI program specifically designed to teach deaf students how to use a ruler. This involves three major instructional design components: (1) characteristics specific to the nature of the task and the terminal objective (ruling up a dimensioned form), (2) those specific to the particular capacities of the student population (deaf students), and (3) the characteristics due to the particular instructional logics, strategies and medium (CAI).[5] All three of these components have generality beyond the specific program they were developed

5. A general discussion of these three instructional design characteristics in the context of CAI is given in Kearsley (1976).

within. Thus, the task analysis reveals the basic subskills involved in using a ruler or measuring instrument and could be used for different student populations or instructional methods. Furthermore, this analysis could be used as part of a related task, e.g., teaching how to convert English linear measurements to metric ones, or for a different terminal objective, e.g., using a ruler in carpentry or dress-making.

The characteristics of the instructional methodology, including logics and strategies, will also carry across the particular student group and subject matter involved in the program. These include:

*using feedback to shape the correct answers
*use of arrows and capital letters as prompts and cues
*use of game strategies to increase attention/interest
*use of enlarged letters, flashing, or underlining for emphasis
*use of a student's name to increase rapport

Thus, techniques such as these can be employed for any subject matter or task and student group, although they will be most important when the students are disadvantaged or the task is relatively complex/boring.

Finally, the characteristics of the design related to the particular student population (the deaf) also have more generality than the specific program described herein. Thus, the present work along with that of others (e.g., Brebner & Hallworth, 1976; Sandals, 1975) using CAI to teach the handicapped suggests:

*the use of concrete examples and minimal abstraction
*strategies which shape behavior rather than those which are didactic
*considerably more use of positive feedback than with normal students
*feedback messages should be constant rather than variable in nature
*screen displays should be simple and express only 1 idea/screen
*instruction should involve as much student participation as possible

These suggestions indicate a further benefit of using CAI with the handicapped, namely, the emergence of a set of prescriptions about how to teach. Because these prescriptions have been stated operationally in the form of a program, they have relatively precise referents and can be reliably demonstrated. This has rather important implications to educational practice and research.

In closing, it must be emphasized that the effectiveness of CAI (and instruction generally) will be a function of how well these three components of instructional design have been accounted for. The fact that the present program involved 3 months of task analysis, about 100 hours of programming time, and the combined knowledge of two experienced teachers, reflects the effort which went into the instructional design. Thus, CAI itself possesses nc magic which will turn poor teaching into good teaching. However, CAI does provide a medium which permits individualized and interactive instruction with monitoring of results and this facilitates instructional design considerably.

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