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PROGRAMMED LEARNING MATERIALS FOR THE BLIND.

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DESCRIPTORS- *BLIND, *BRAILLE, *SCIENCE EDUCATION, *PROGRAMED INSTRUCTION, ADOLESCENTS, INSTRUCTIONAL MATERIALS, JUNIOR HIGH SCHOOL STUDENTS, LEARNING PROCESSES, PROGRAMED MATERIALS, SCIENCE INSTRUCTION, SCIENCE MATERIALS, SCIENCE PROGRAMS, STIMULUS DEVICES,

THIS STUDY WAS DESIGNED AS A PRELIMINARY INVESTIGATION TO DETERMINE THE FEASIBILITY OF USING PROGRAMED LEARNING MATERIALS WITH BLIND STUDENTS. FOUR TYPES OF STIMULUS-REPONSE MODES FOR PROGRAMED INSTRUCTION WERE DEVELOPED--AUDIO STIMULUS-AUDIO RESPONSE, AUDIO STIMULUS-BRAILLE RESPONSE, BRAILLE STIMULUS-AUDIO RESPONSE, BRAILLE STIMULUS-BRAILLE RESPONSE. A PILOT TESTING PROGRAM REVEALED THE BRAILLE STIMULUS-BRAILLE RESPONSE MODE WAS MOST APPROPRIATE. TESTS DETERMINED THAT THE MOST EFFICIENT BRAILLE STIMULUS-BRAILLE RESPONSE FORMAT WAS A BOOKLET IN WHICH THE BRAILLE FRAME APPEARED ON ONE PAGE AND THE CORRECT RESPONSE ON THE NEXT. THE STUDENT RESPONDED WITH A BRAILLE WRITER OR BRAILLE SLATE AND STYLUS. COMMERCIALLY DEVELOPED PROGRAMS FOR JUNIOR HIGH SCHOOL SCIENCE WERE MODIFIED FOR USE WITH BLIND STUDENTS. TWO 50 FRAME PROGRAMS REPRODUCED IN BRAILLE WERE TESTED WITH 57 BLIND JUNIOR HIGH SCHOOL STUDENTS. RESULTS SHOWED THEY COULD HANDLE THESE PROGRAMED MATERIALS IN A REASONABLE AMOUNT OF TIME AND WITH A HIGH DEGREE OF ACCURACY. INSTRUCTIONS WERE FOLLOWED WITH MINIMAL DIFFICULTY. PERFORMANCE IMPROVED WITH SECOND BOOK. IN MODIFYING THE PROGRAM FOR USE WITH THE BLIND, 32 SYMBOLS WERE DEVELOPED FOR THE MOST FREQUENTLY USED SCIENCE TERMS IN ORDER TO REDUCE THE BULK OF BRAILLE MATERIALS. TO DETERMINE WHETHER BLIND STUDENTS COULD DISCRIMINATE AMONG THE SYMBOLS AND BETWEEN THE SYMBOLS AND BRAILLE, 43 BLIND STUDENTS (GRADES SIX TO TEN) WERE GIVEN TESTS IN THE FORM OF CHECKERS AND CHECKERBOARDS WHICH CONTAINED THE VARIOUS SPECIAL SCIENCE SYMBOLS. STUDENT SCORES IMPROVED AS IQ ROSE, JUNIOR HIGH STUDENTS SCORED BETTER THAN SIXTH GRADERS AND HIGH SCHOOL STUDENTS REACTED NEGATIVELY AND DID NOT DO WELL. ON SECOND TRIALS STUDENTS REQUIRED LESS TIME AND SCORED FEWER ERRORS. THE APPENDIXES CONTAIN SAMPLE SCIENCE PROGRAMS ON "PHYSICAL AND CHEMICAL CHANGES," "SYMBOLS AND FORMULAE," AND "THE PLASTIDS." (TM)

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George G. Mallinson

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In addition, acknowledgment is due Mr. Theodore Waller, of The Grolier Society, for special permission to adapt and use sections of the programmed materials cited herein, without charge.

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CHAPTER I

INTRODUCTION

Background of the Study

On May 1, 1961, a Center for Orientation and Mobility was established at Western Michigan University for training of Orientation and Mobility Specialists to work with the blind. The Center was established under OVR Grant No. 284-61, after two years of negotiation with the Veterans Administration and the Office of Vocational Rehabilitation, now known as the Vocational Rehabilitation Administration, Department of Health, Education, and Welfare. In addition to the funding received from the VRA for this program, grants have been received for a training program for Home Teachers for the Blind and many short conferences for personnel serving the blind.

The philosophy on which the initial program of the Center for Orientation and Mobility was based emerged the work of Dr. Richard E. Hoover, now of Johns Hopkins University Medical School. Dr. Hoover began investigating the modern concept of orientation and mobility, together with the associated social and emotional components, at Valley Forge General Hospital during World War II. The program for training the blinded veteran and Orientation and Mobility Specialists was transferred to the Veterans Hospital at Hines, Illinois, in 1948. It is now administered at the Federal level through the Blind Rehabilitation Services, Veterans Administration, Washington, D.C., of which Dr. Russell C. Williams is Chief.

The cooperative program with Western Michigan University was motivated by the need for a greatly-increased number of such specialists for serving blinded veterans through the Veterans Administration; and for extending such services to non-veterans, both child and adult, for whom the services are, for all practical purposes, not now available. The latter servicing is of major interest to the Vocational Rehabilitation Administration. Suffice to say, the program at Western Michigan University has expanded since May 1, 1961, to serve the needs of blinded persons at all age levels, since the concept of physical orientation and mobility has proved to be applicable with children as young as seven years.

This program has been complemented with another program for training Home Teachers of the Blind. Such a teacher identifies the blind person in the home and provides training in various personal skills and mobility within the home. In addition, the home teacher provides information concerning other modes of assistance needed by and available to the blind client.

The increased mobility and accompanying broadening of the physical environment of the blinded person places stresses on an area in which the resources are already taxed beyond limits, namely, academic and intellectual training. There are too few teachers trained to serve the academic and intellectual needs of the 75,000 blinded persons in the United States who are listed on one or more rosters of the blind. Although these rosters are incomplete and out of date, estimates of various organizations, such as the American Foundation for the Blind, indicate that the total number of blinded persons in the United States is about 370,000. Extrapolations of the data that are available indicate that between 60% and 70%, or about 240,000, are in need of some form of academic training.

The overall shortage of teachers in the United States has reduced the number of educational programs for the blind. The problem has been accentuated by expanding services for greater numbers of blinded persons, the problems of recruiting personnel interested in acquiring the time-consuming training needed, and especially by the shortage of sophisticated learning materials. Numerous observations of classes and educational programs for the blind at the Upjohn School, Kalamazoo, Michigan; Ann J. Kellogg School, Battle Creek, Michigan; Academic School of the Veterans Administration Hospital, Hines, Illinois; and State School for the Blind, Lansing, Michigan, indicate that classroom experiences with groups as large as 20 can be used effectively in the academic training. However, the time the teacher must spend individually with the blinded students in providing help on problems, evaluating their efforts, and correcting errors is about ten times that needed with a sighted student. Any learning procedure, either involving the activity of the teacher or the use of new materials that would reduce the time needed for individual instruction and still accomplish the desired aims, would help alleviate the strains resulting from the situations described above.

During the period 1960-62, the Investigator and the staff members of the Center for Orientation and Mobility for the Blind, and personnel of the Division of Special Education of Western Michigan University, studied the possibilities of using programmed materials in various aspects of the academic programs for blinded persons. Literature on programming was obtained and read by all persons concerned. The two references named below were probably the ones that indicated the merits of using programmed learning materials with sighted persons, although the enthusiasm expressed by many writers was not shared completely.

1. Lumsdaine, A. A.; and Glaser, Robert, (eds.). Teaching Machines and Programmed Learning. Washington, D.C.: Department of Audio-Visual Instruction, National Education Association. 1960. 724p.

2. Stolurow, Lawrence M. Teaching by Machine. Cooperative Research Monograph, No. 6, Office of Education, U.S. Department of Health, Education, and Welfare, Washington, D.C. 1961. 173p.

There was not, however, except for casual references, any literature available concerning the use of programmed materials with the blind.

Meanwhile, conferences were held with, among others, Dr. John K. DuPress, Director of Technological Research, and Miss Kathern F. Gruber, formerly Director, Division of Program Development, American Foundation for the Blind, Inc.; Dr. Robert H. Thompson, Head, Michigan State School for the Blind; Dr. Lewis D. Eigen, Dr. Susan Meyer Markle, and other staff members of the Center for Programmed Instruction, Inc., New York, New York; and Mr. C. Warren Bledsoe, and other personnel in the Division of Services for the Blind, Vocational Rehabilitation Administration, concerning the potential of using programmed materials for the purpose indicated. Without exception, it was believed that there might be values in using programmed materials with blind persons, provided they were properly modified. Those consulted confirmed, however, that the use of programmed materials with blind persons had not been explored. They also indicated that the nature of braille made the direct reproduction of some programmed materials impossible, and that adaptations would be necessary. Also, it was generally agreed that perceptual processes involved with programmed materials presented visually might differ from the perceptual processes involved with those presented through other sensory media. There was no agreement concerning the probable disparity.

Several possibilities existed for stimulus and response modes that might prove to be most effective. One was the use of auditory stimuli with either verbal or braille responses. Another was the use of braille stimuli with either verbal or braille responses. There was not consensus concerning the optimal combination.

It was recognized that all the factors related to the problem could not be included successfully in an initial investigation. Therefore, this study was designed as a preliminary investigation to answer some of the ramifications of the entire problem.

The Problem

As indicated in the previous section, it was believed that the development of programmed learning materials for the blind might have value in assisting the teacher in checking the work of blind students. Instead of the traditional one-to-one ratio usually required, if successful, a programmed technique might allow the student to check his own learning. Hence, the original problem sought the answers to these questions:

1. What formats of stimulus and response modes seem to be most suitable for using programmed materials with the blind?

2. What personal factors of the blind person may influence the use of programmed materials?

3. What may be the optimal length of a program that may be suitable for use with the blind?

4. How is the achievement of blind students on a program related to the stimulus-response mode employed?

It should be stated here that, as a result of the initial investigations, a second major problem emerged, namely, the development of symbolic science learning for the blind. The details of the investigation of this second problem are discussed in the second section of this report. The methods employed in Phase I of the investigation are presented in Chapter II.

CHAPTER II

METHODS EMPLOYED IN DEVELOPING PROGRAM FORMATS

Purpose

This chapter describes the (1) methods employed in selecting programmed materials for adaptation; (2) development of alternate formats for programmed materials for blind students; and (3) techniques used to test the formats.

Selection of Programmed Materials

Initially, the main purpose of this investigation was to determine whether or not programs might be useful in evaluating the learning of blind students. Hence, it was decided to adapt programmed materials already available, rather than develop a new set. Because of his scientific background and interest, the Project Director decided to adapt programmed materials for science at the junior-high-school level. There were three reasons for this decision:

1. Junior-high-school students would be mature enough to work independently as required by programmed instruction. Also, these students are more willing to participate in experiments than are high-school students.

2. Students at this level are presumably competent in grade two braille.

3. The Project Director has had many years of experience in working with science learning materials and teaching problems at the junior-high-school level.

Thus, the first step was to search for commercially-prepared programmed learning materials in science designed for sighted junior-high-school students. The search was conditioned by two criteria:

1. The materials should contain a minimal number of graphs, charts, formulae, phonetic spellings, and symbols not readily converted into braille.

2. The materials should have been produced by a reputable company, with experience in programmed instruction.

After an extensive search, it was decided to adapt for use in this study the TMI-Grolier Programed Textbook: General Science - Biology and Chemistry, Volume 1 of 2 and Volume 2 of 2. These materials were distributed by Teaching Materials Corporation, a Division of Grolier Incorporated, 575 Lexington Avenue, New York, New York. Permission to adapt these materials was granted in a letter from Mr. Theodore Waller, Editor-in-Chief of Teaching Materials Corporation, which states in part:

> "You may take this letter, however, as your authority to translate the two general science programs into Braille, under the conditions and limitations specified in your letter [of February 5, 1963]."

For the pilot project, designed to test the various initial formats, a 20-frame program in biology was adapted from Unit 1, "Introduction to Cells," in Volume 1 of 2; and from Unit 2, "The Plastids," in Volume 1 of 2 of the TMI-Grolier materials. For testing the format that was found to be most appropriate, two 50-frame programs were developed. The first was an adaptation of a 42-frame unit in Volume 2 of 2 of the TMI-Grolier materials, entitled Chemistry, Unit 3, "Symbols and Formulae." To this, the Investigator added a few additional frames to conclude the presentation and make its length more comparable with that of the other unit. The second unit was composed of the first 50 frames from Volume 2 of 2, Chemistry, Unit 4, "Physical and Chemical Changes." Copies of the materials that were adapted appear in Exhibits D and F of the Appendix.

Design and Testing of the Programmed Formats

Once the test materials had been adapted, it was necessary to design some formats for programmed instruction that might be suitable for blind students. As indicated earlier, the typical programmed format used by a sighted student would not be suitable for blind students. Hence, it was decided to develop and test the four following stimulus-response modes:

1. Audio stimulus - audio response:

(the student received the stimulus by listening to a tape recording; responded by speaking into a tape recorder)

2. Audio stimulus - braille response:

(the student received the stimulus by listening to a tape recording; responded in braille)

3. Braille stimulus - audio response:

(the student received the stimulus by reading a braille booklet; responded by speaking into a tape recorder)

4. Braille stimulus - braille response:

(the student received the stimulus by reading a braille booklet; responded in braille)

For the audio stimulus, a tape was prepared by Mr. Garrard MacLeod of Station WMUK, at Western Michigan University. On one tape, the instructions were given; then each frame was read, followed by a tone, to indicate the end of the frame. Intervals of 1, 2, and 3 seconds between the frames were tested for making the response. It was possible for the student to make the response between the tone and the next frame and check his response later. Or, if he needed more time, he could turn off the tape recorder and make the response. It was possible for the student to make his response either by speaking into a tape recorder, or writing it in braille, depending on which response mode was being tested. On preliminary testing the one-second interval proved to be too short, and the three-second interval unduly long. Hence, the final tape that was used in the pilot testing had intervals of two seconds between the tone and the next frame. Copies of these tapes were reproduced through the services of Mrs. Marie McMahan of the Audio-Visual Center of Western Michigan University.

For the braille-stimulus mode, the 20-frame biology unit was translated into braille by Miss Ellen Van Vliet, Teacher of the Blind in Berwyn, Illinois. Copies of this material were reproduced through the auspices of the Johanna Bureau for the Blind, at the Chicago Public Library.

The four stimulus-response modes outlined above were then pilot tested with blind students in the Berwyn Public Schools, under the direction of Miss Van Vliet; and with students in the Kalamazoo Public Schools, under the supervision of Mr. George Ossentjuk, Itinerant Teacher for the Blind. From these pilot tryouts, it was immediately apparent that the first three stimulus-response modes were far too complicated and difficult for students to follow. The audio-stimulus techniques proved to be extremely frustrating, particularly in terms of responding. The tape with the 3-second intervals required too long a time to complete. With the tape with the shorter intervals, students still had much difficulty in either making a braille or an auditory response. Not one of the pilot group finished the program; the students either refused to continue or could not keep up with the tape.

It became obvious that a braille-stimulus mode would be more appropriate. However, even with a braille stimulus, students became confused in making an auditory response into a tape recorder. The shift from one material to another proved to be a severe problem. The efforts showed, however, that the braille stimulus - braille response mode would work with students of the age level involved in this study.

The next task involved the development of a braille - braille format that could be used efficiently with blind students. For this part of the pilot study, four possible braille stimulus - braille response modes were developed. They were as follows:

1. A "teaching machine" in which the stimuli were in braille and the responses recorded on a roll of adding machine tape, with the aid of a braille slate and stylus. Two forms of the programmed materials were used with the machine, one with two frames per page, and one with three frames per page.

2. A booklet in which two frames were presented on each page. A perforation was made vertically three inches from the right-hand edge of the paper, and the three-inch section was folded over the front side. The correct responses appeared under the "fold-over." The student recorded his response on the fold-over with a braille slate and stylus and then compared his response with the correct one.

3. A booklet in which one frame was written on each sheet. A perforation was made horizontally three inches from the bottom, and the three-inch section was folded upward over the front side. The correct response to the frame appeared under the "fold-up." The student used a braille slate and stylus to record his response on the fold-up, and then compared his response with the correct one.

4. A booklet in which the first 10 frames appeared each at the top of one page, with the correct response at the top of the next. The student was instructed to read the frame and record his response with a braille writer. He then turned the page and compared his response with the correct one. The same procedure

was followed for the second 10 frames, but these appeared at the bottoms of the booklet pages with the correct responses in the centers of the following pages.

Pictures of the first three trial "braille - braille" formats are shown in the photographs that appear on the next page. These, together with the fourth just described, were pilot tested in the Berwyn and Kalamazoo Public Schools under the supervision of Miss Van Vliet and Mr. Ossentjuk. It was found that the first three were too complicated and bulky for students to handle. They all required the use of a braille stylus and slate, a form of writing braille not currently stressed in day-school classes for blind students at the present time. In addition, the first format required much manual dexterity to manipulate the roll of tape; the second and third both utilized expendable materials that could be used only once. For these reasons, these three formats were not considered satisfactory.

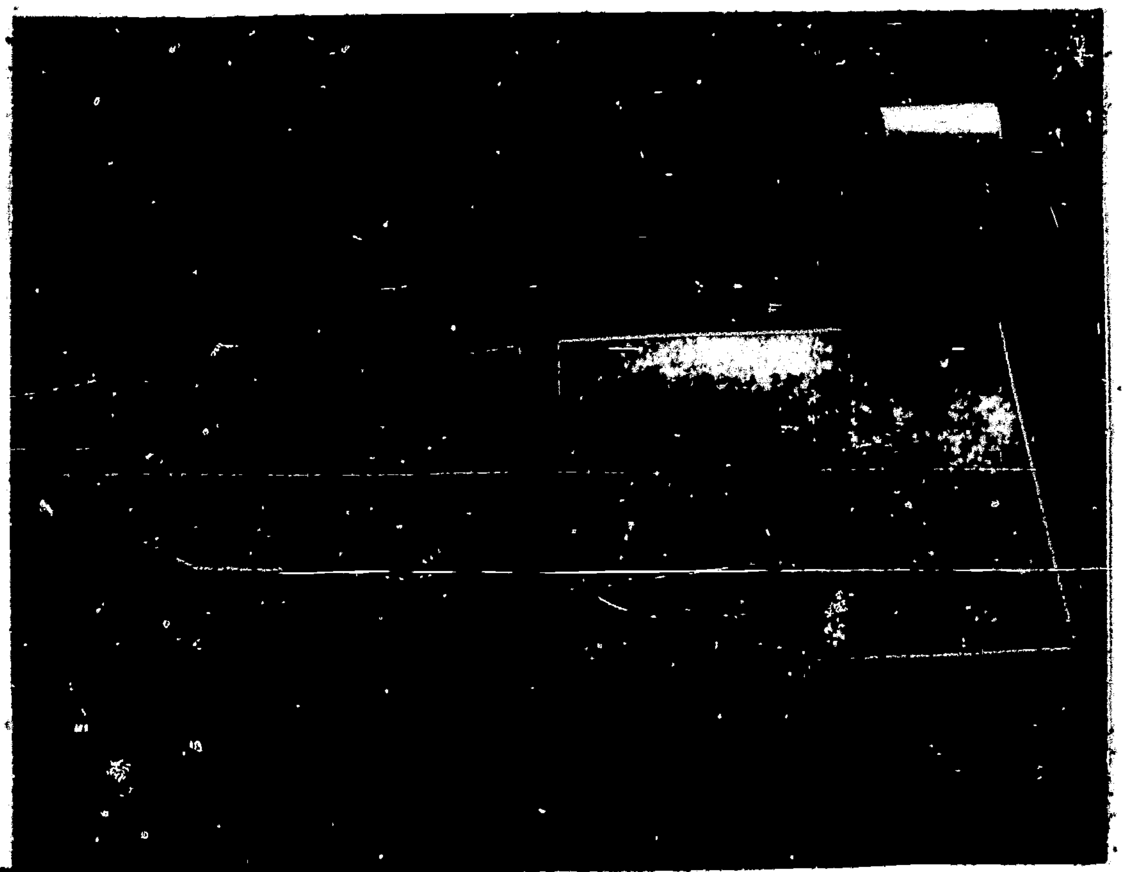
The last format described, in which the information frame was on one page and the response on the other, was found satisfactory. These materials could be reused and the student responded with a braille writer, a machine with which he is likely to be familiar. A typed copy of the 20-frame trial program used in the pilot testing is appended to this report (Exhibit B). The actual booklet is also appended (Exhibit C). The final testing of this latter format is described in the next section.

Final Testing of the Programmed Format

Once the appropriate braille - braille format was chosen, the next task was to translate and reproduce the two 50-frame units mentioned on page 6. These tasks were accomplished through the services of Miss Van Vliet and the Johanna Bureau for the Blind, respectively. Copies of the final two programs thus developed are appended to this report in Exhibits D, E, F, and G of the Appendix. It should also be noted that one minor change was made between the pilot and the final booklets. The 20-frame pilot booklet was hinged at the left, whereas the two final 50-frame booklets were hinged at the top. It was found that this arrangement was easier for the students to handle.

Once the final booklets were completed, they were administered to students enrolled in the Michigan State School for the Blind, Lansing, Michigan; the Illinois Braille and Sight-Saving School, Jacksonville, Illinois; and the Missouri School for the Blind, St. Louis, Missouri. The testing was supervised by Miss Ruth Kaarlela of the Institute of Blind Rehabilitation, Western Michi-

Figure 1



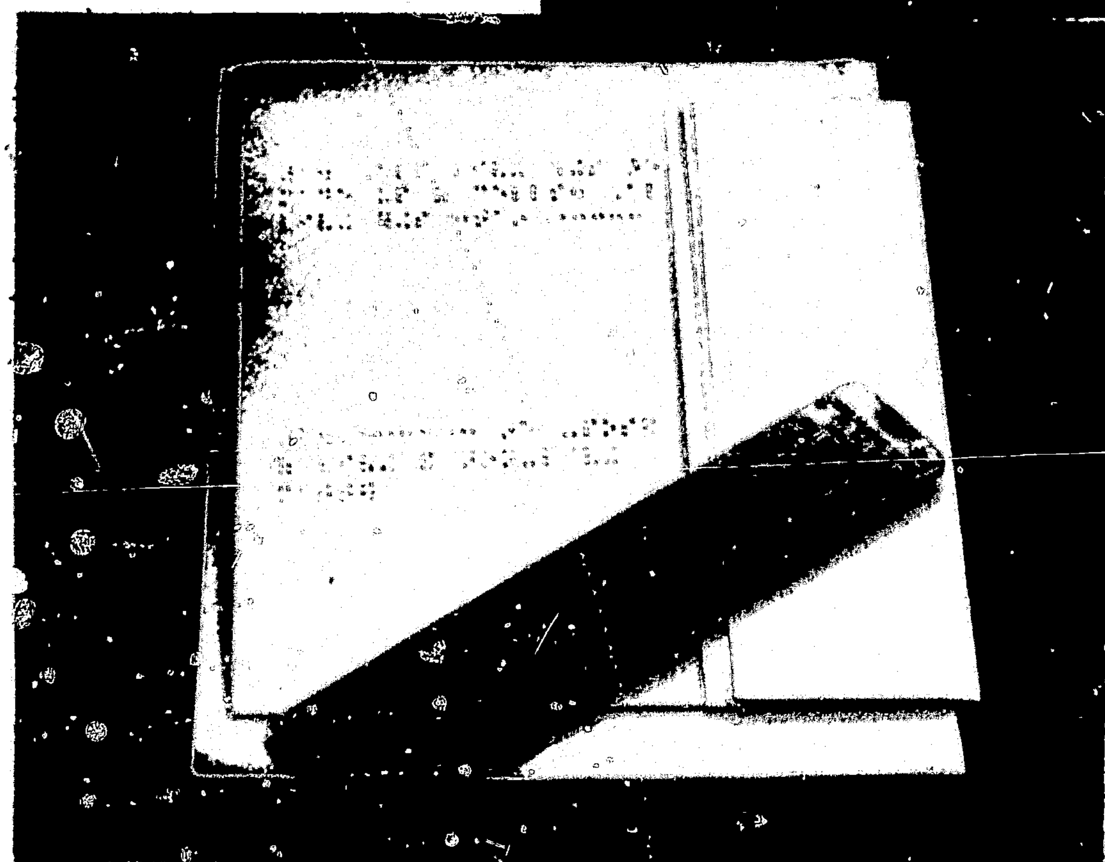
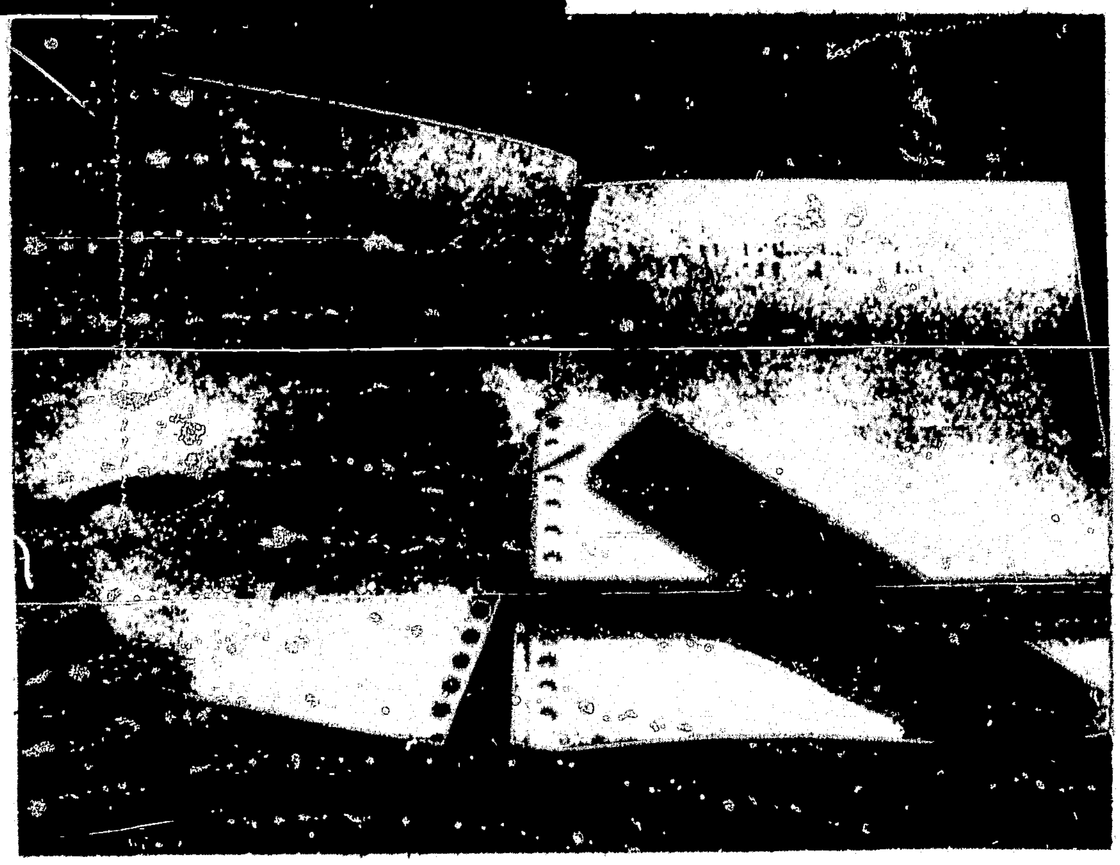


Figure 2

Figure 3



gan University. In these final testings, students were given their choice of recording their responses with either a braille writer or braille stylus and slate. The results obtained with the 57 blind subjects appear in Chapter III.

CHAPTER III

RESULTS, CONCLUSIONS, AND DISCUSSION OF PHASE I OF THE STUDY

Purpose

The purpose of this chapter is to describe the results and discuss the conclusions of the first phase of this investigation involving the development and testing of programmed instructional materials for science for blind students.

Results

As indicated in the previous chapter, two 50-frame programs were reproduced in braille and tested with 57 students in three schools for the blind in the Midwest. The results of these three testings appear in Tables I and II that follow:

Table I

RESULTS OF ADMINISTERING PROGRAMMED BOOK I
TO 57 BLIND STUDENTS

Student Number	Response	Required	Total Number of Responses (out of 65)	Correct Responses	Incorrect Responses
1	Braille writer	49	58	54	4
2	Braille writer	49	60	57	3
3	Slate	46	50	41	9
4	Braille writer	47	35	24	11
5	Slate	49	58	52	6
6	Slate	48	60	58	2
7	Braille writer	44	63	57	6
8	Braille writer	46	65	65	0
9	Braille writer	48	48	45	3
10	Slate	47	56	50	6
11	Braille writer	45	64	60	4
12	Braille writer	49	38	25	13
13	Slate	49	35	28	7
14	Slate	48	52	48	4
15	Braille writer	45	59	54	5
16	Braille writer	47	60	58	2
17	Braille writer	47	57	50	7
18	Slate	49	34	28	6
19	Slate	49	56	41	15

Table I (continued)

Student Number	Mode of Response	Time Required	Total Number of Responses (out of 65)	Correct Responses	Incorrect Responses
20	Slate	49	32	27	5
21	Slate	49	27	25	2
22	Braille writer	47	65	63	2
23	Braille writer	49	65	33	32
24	Slate	49	25	15	7
25	Slate	49	18	16	2
26	Slate	49	36	35	1
27	Braille writer	43	64	62	2
28	Slate	49	38	37	1
29	Braille writer	49	24	23	1
30	Slate	49	37	29	8
31	Slate	49	65	65	0
32	Slate	44	65	65	0
33	Braille writer	49	39	29	10
34	Slate	49	63	63	0
35	Braille writer	49	35	21	14
36	Braille writer	33	65	61	4
37	Braille writer	45	56	34	22
38	Braille writer	50	63	61	2
39	Braille writer	41	65	58	7
40	Slate	50	55	50	5

Table I (continued)

Student Number	Mode of Response	Time Required	Total Number of Responses (out of 65)	Correct Responses	Incorrect Responses
41	Braille writer	50	30	21	9
42	Slate	50	50	40	10
43	Braille writer	41	65	60	5
44	Slate	44	65	46	19
45	Braille writer	50	38	29	9
46	Slate	50	49	41	8
47	Braille writer	45	65	62	3
48	Braille writer	50	55	52	3
49	Slate	45	65	59	6
50	Braille writer	32	65	65	0
51	Slate	50	22	21	1
52	Braille writer	45	50	32	18
53	Slate	45	25	14	9
54	Slate	50	36	24	12
55	Braille writer	38	65	63	2
56	Braille writer	33	65	58	7
57	Braille writer	50	45	42	3

Table II

RESULTS OF ADMINISTERING PROGRAMMED BOOK II
TO 57 BLIND STUDENTS

Student Number	Mode of Response	Time Required	Total Number of Responses (out of 54)	Correct Responses	Incorrect Responses
1	Braille writer	48	54	53	1
2	Braille writer	47	54	50	4
3	Slate	35	50	50	0
4	Braille writer	40	45	39	6
5	Slate	50	50	48	2
6	Slate	48	49	49	0
7	Braille writer	34	54	53	1
8	Braille writer	36	54	52	2
9	Braille writer	40	46	46	0
10	Slate	40	50	48	2
11	Braille writer	38	54	54	0
12	Braille writer	52	37	30	7
13	Slate	48	38	35	3
14	Slate	44	50	49	1
15	Braille writer	40	54	52	2
16	Braille writer	35	54	54	0
17	Braille writer	38	54	53	1
18	Slate	40	54	50	4
19	Slate	38	54	53	1

Table II (continued)

Student Number	Mode of Response	Time Required	Total Number of Responses (out of 54)	Correct Responses	Incorrect Responses
20	Slate	52	48	48	0
21	Slate	52	43	42	1
22	Braille writer	36	54	53	1
23	Braille writer	28	54	44	10
24	Slate	50	54	53	1
25	Slate	52	40	25	15
26	Slate	45	54	53	1
27	Braille writer	29	54	53	1
28	Slate	52	34	34	0
29	Braille writer	52	45	44	1
30	Slate	47	54	49	5
31	Slate	36	54	52	2
32	Slate	35	53	53	0
33	Braille writer	41	54	44	10
34	Slate	35	54	54	0
35	Braille writer	52	43	39	4
36	Braille writer	30	54	50	4
37	Braille writer	33	54	32	22
38	Braille writer	44	54	54	0
39	Braille writer	28	54	51	3
40	Slate	50	53	50	3

Table II (continued)

Student Number	Mode of Response	Time Required	Total Number of Responses (out of 54)	Correct Responses	Incorrect Responses
41	Braille writer	50	45	39	6
42	Slate	46	53	42	11
43	Braille writer	29	54	51	3
44	Slate	33	54	50	4
45	Braille writer	50	54	47	7
46	Slate	45	54	50	4
47	Braille writer	37	54	50	4
48	Braille writer	43	54	45	9
49	Slate	38	54	54	0
50	Braille writer	24	54	52	2
51	Slate	50	34	27	7
52	Braille writer	37	54	43	11
53	Slate	43	54	47	7
54	Slate	50	54	49	5
55	Braille writer	27	54	52	2
56	Braille writer	24	54	51	3
57	Braille writer	50	54	49	5

Discussion of the Results

An examination of the data in the preceding tables indicates that most students were able to complete the programmed materials in a reasonable amount of time. Generally, the average time was one minute or less per frame. In addition, the students were able to follow the instructions with minimal difficulty, and responded with a high degree of accuracy. The numbers of errors were quite small. It may be noted that performance improved with the second book.

One may conclude that a programmed learning technique, involving a braille stimulus and a braille response, the latter with either a braille writer or braille stylus and slate, may be used effectively with blind students, particularly when used to check the acquisition of knowledge of primary materials presented initially by a teacher. Such a technique, appropriately exploited, may well reduce the amount of time required for a teacher to check personally a student's work, and thus increase his time for primary instruction.

Programs that involved auditory-stimulus modes or auditory-response modes with tape recorders proved to be highly ineffective. This generalization, of course, applies only to the manner in which the auditory technique was used in this investigation. The problems the students had with using the equipment with the auditory technique, and the far greater time involved, made statistical comparisons unnecessary.

From this phase of the study, however, a second problem for investigation emerged. As stated earlier, a problem encountered in translating programmed materials for sighted children into braille is the great increase in bulk of the finished product. The second 50-frame final trial program on "Physical and Chemical Changes" covered 10 printed pages in the original TMI-Grolier materials. When translated into braille, the material covered 31 pages that were about 25% larger. Thus, braille books are bulkier and more difficult for students to handle.

It occurred to the researchers that if some technique could be devised, whereby the length of braille materials could be reduced, even slightly, the problem might be somewhat alleviated. Hence, this investigation was extended to the second phase described in the next sections of this report.

CHAPTER IV

BACKGROUND OF PHASE II

Purpose

The purpose of this chapter is to describe the background and implications of the second phase of this study, that emerged from developing a format for programmed learning materials for use with blind students.

Background

As indicated earlier, whenever learning materials designed for sighted students are translated into braille, the size of the product increases greatly. One of the commercial programmed materials that was adapted for Phase I of this study consisted of 15 units of instruction, covering about 315 pages. Had the entire book been translated into braille, it would have required about 1,000 pages. Since the paper used in braille books is much heavier than that used in ink-print books, the problems of bulk become obvious.

An examination of science materials designed for sighted students at the junior-high-school level indicates that a number of terms common to science are repeated frequently. Among them are, "Law of Conservation of Mass and Energy," "Law of Universal Gravitation," and "heat energy." When such terms are translated into braille, much space is required. It was thought that if these repetitive science terms could be replaced with a simple, meaningful symbol, the bulk of science materials for the blind could be somewhat reduced. Although this technique has been suggested by others, a search of the literature failed to reveal any studies similar to this one.

The methods employed in developing and testing such symbols are discussed in Chapter V.

CHAPTER V

METHODS EMPLOYED IN DEVELOPING SYMBOLIC SCIENCE LEARNING FOR THE BLIND

Selection of Science Terms and Development of Symbols

The first step in the development of symbols was the selection of "key" science terms. Thus, a survey was made of all leading textbooks for science at the junior-high-school level, as well as a number of major state syllabi and courses of study for junior-high-school science. Lists were made of the science terms that appeared at least 10 times in any one source. In addition, a tally was made of the number of times each term appeared in each source subsequently surveyed. The terms were checked also against leading vocabulary lists of important science terms for the secondary-school level. From this master list, the 50 terms that appeared most frequently in the materials thus examined were selected.

The initial list of 50 terms was then analyzed to determine those for which there were already-established symbols. Examples included terms such as "wave," (∿); "electrical cell," (|ı); "battery," (|ı|ı); and "heat energy," (Δ). If available, the established symbols were used in this study.

For the other terms, an attempt was made to develop symbols that would be empirically sound, namely, appropriate to the idea related to the term. In other words, the symbol must <u>not</u> be merely an abstract figure, but must carry with it a significance for the sighted child as well as the blind child. For example, the symbol developed for the term, "Law of Universal Gravitation," was a double arrow ($\leftrightarrow$), to imply the mutuality of gravitational attraction. The symbol for "atmosphere" was an arrow pointing upward ($\uparrow$), which is used in chemistry to denote a gas; that for the "lithosphere," an arrow pointing downward ($\downarrow$). Tentative symbols were thus developed for all those terms for which common symbols did not already exist.

Some difficulty was encountered in developing empirically-sound symbols for all 50 terms. Hence, a few terms, even though important, were discarded, including "air mass," "density," and "inertia." A few terms with already-existing symbols were also discarded because the symbols proved to be difficult to reproduce on braillon paper. Among such terms were "AC generator" and "DC generator." In addition, the symbols that were developed had to be restricted to the vertical height of the regular six-dot braille cell.

From these initial efforts, a list containing 38 terms and corollary symbols was assembled. This list was submitted to members of the science staff at Western Michigan University; personnel of the Institute for Blind Rehabilitation, Western Michigan University; and selected members of the National Association for Research in Science Teaching for review from the viewpoint of empirical soundness of the symbols, as well as their ability to be recognized tactually by a non-sighted child.

As a result of this jury analysis, further changes were made. The experimental list of symbols was then "pilot tested" with students at the Missouri School for the Blind under the supervision of Mr. Robert McQuie, Guidance Director. Again, minor revisions were made and a list consisting of 32 terms and symbols emerged. These appear in Table III on page 23.

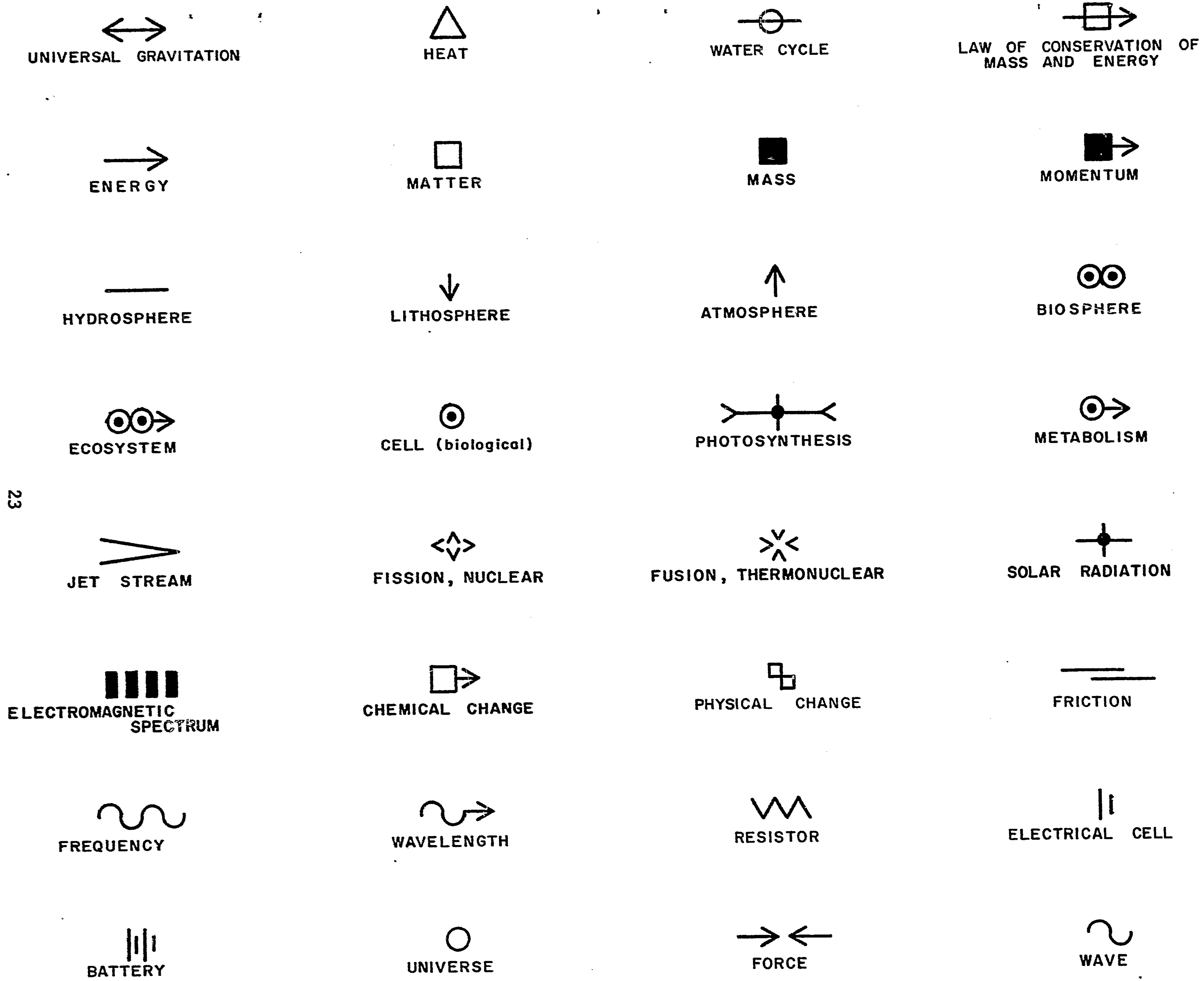
Testing Procedures

When the list of science symbols was assembled, a technique had to be devised to test both the "internal consistency" and "external consistency" of discrimination. Internal consistency refers to the ability of the blind junior-high-school student to distinguish among the science symbols. External consistency refers to the ability of the blind student to distinguish between the science symbols and braille cells. Obviously, if the student could not discriminate in these ways, the symbols would have little value.

An attempt was made to devise an efficient, but interesting, testing technique that might appeal to students of the junior-high-school age level, involving the "checker game" format. "Checkers" were made, to which the individual science symbols were affixed, and "checkerboards," containing certain of the symbols, were also prepared. The blind student's task then was to place the appropriate checker on the checkerboard containing the matching symbol.

To test "internal consistency," the list of 32 science symbols was divided at random into four sets of eight symbols each. These sets were arbitrarily designated "A," "B," "C," and "D."

Table III


UNIVERSAL GRAVITATION
HEAT
WATER CYCLE
LAW OF CONSERVATION OF MASS AND ENERGY
ENERGY
MATTER
MASS
MOMENTUM
HYDROSPHERE
LITHOSPHERE
ATMOSPHERE
BIOSPHERE
ECOSYSTEM
CELL (biological)
PHOTOSYNTHESIS
METABOLISM
JET STREAM
FISSION, NUCLEAR
FUSION, THERMONUCLEAR
SOLAR RADIATION
ELECTROMAGNETIC SPECTRUM
CHEMICAL CHANGE
PHYSICAL CHANGE
FRICTION
FREQUENCY
WAVELENGTH
RESISTOR
ELECTRICAL CELL
BATTERY
UNIVERSE
FORCE
WAVE

The symbols were reproduced by hand-tooling a piece of copper foil. This copper mask was then used to reproduce the symbols in quantity on special braillon paper with a Thermoform machine. From these braillon symbols, sets of "A," "B," "C," and "D" checkers were then made by gluing the individual symbols to checkers. A notch was cut into the "top" of each checker so that the blind child could orient each checker. Such orientation was necessary for discriminating between symbols, such as those for the atmosphere and lithosphere. All "A" and "B" symbols were affixed to red checkers; all "C" and "D" symbols were affixed to black checkers. This "color coding" assisted the test administrator in checking responses, as will be noted in the testing instructions that follow. Then, sets of "A-C" and sets of "B-D" checkers were assembled in boxes. A set of each type accompanies this report in Exhibit H of the Appendix.

The next step was to construct special four-by-four "checkerboards," on which a total of 16 symbols were affixed. Four types of boards were prepared, one containing A-B symbols; one, B-C; one, C-D; and one, D-A. The arrangements of the symbols on these four types of checkerboards are shown in Tables IV through VII that follow on pages 25 through 28, respectively. Sets of the boards accompany this report in Exhibit I of the Appendix.

The instructions to the test administrator for testing "internal consistency" follow:

<u>Suggestions for the Administration of Part I of the Test:</u>

The purpose of Part I of the test is to determine whether the blind student can "discriminate internally" among the various science symbols.

1. Each student should be tested with checkerboards A-B, B-C, C-D, and D-A. It is suggested that at the beginning of a testing period, each student be given a box of A-C checkers. Each student should open the box and spread the 16 checkers at random in front of him along the near edge of his desk or table. The test administrator should be certain that all checkers are "face up" with the braillon symbols showing. Also, at this time the student should be informed that the "top" of the checker can be detected by the notch in the edge. The notch should be pointing away from the student.

2. The students can then be given the checkerboards marked "A-B" (with red borders). They should be instructed to feel the symbols on the board, find a checker with an identical symbol (remembering the notch on the checker is the "top"), and place the checker over the corresponding symbol on the board. The stu-

Table IV

A - B

(USE A-C CHECKERS)

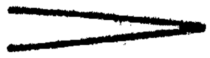
			
A_2	B_2	B_7	A_8
			
B_5	A_6	A_1	B_3
			
A_4	B_1	B_6	A_5
			
B_4	A_3	A_7	B_8

Table V

B — C

(USE B-D CHECKERS)

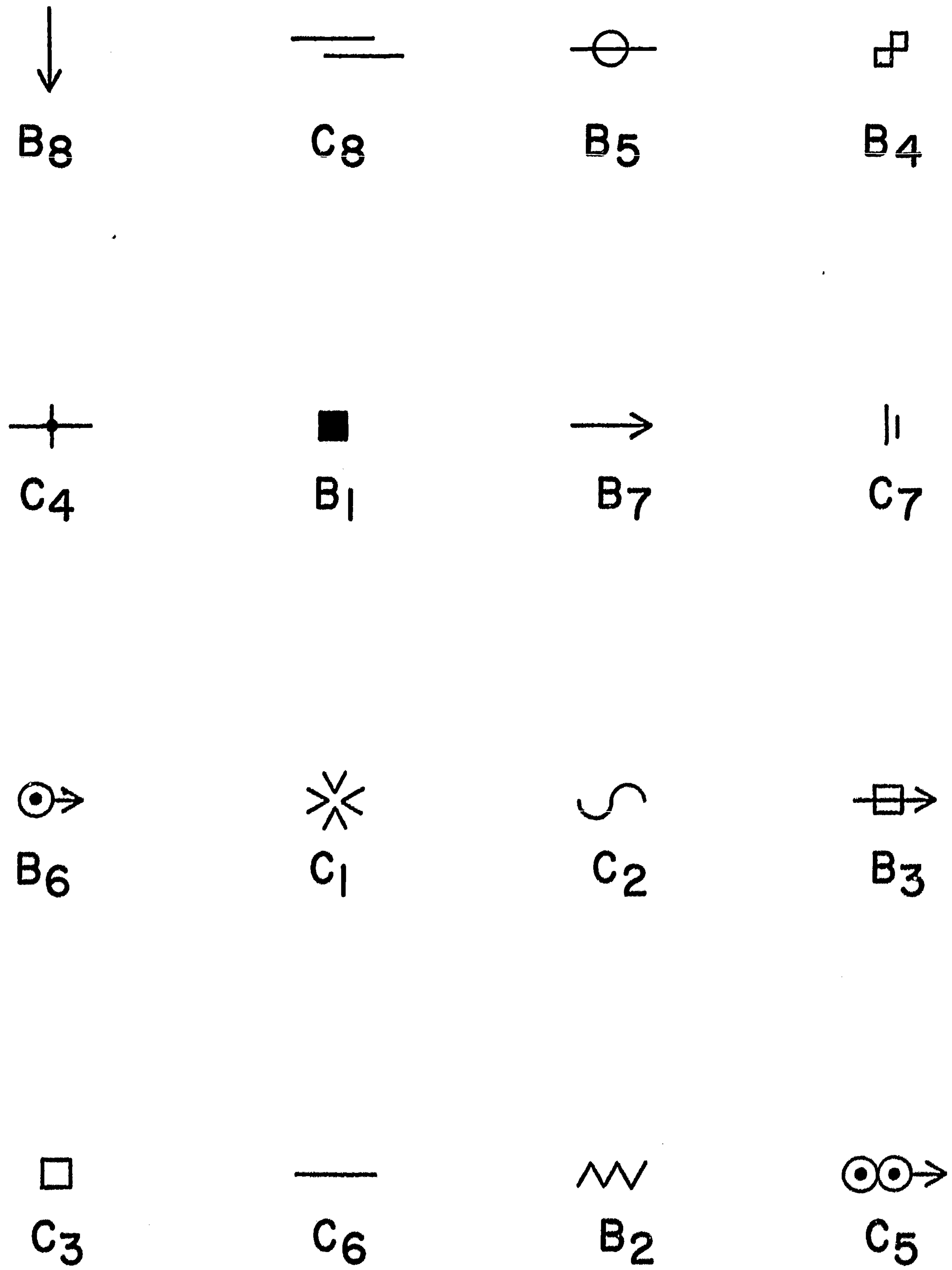


Table VI

C – D

(USE A–C CHECKERS)

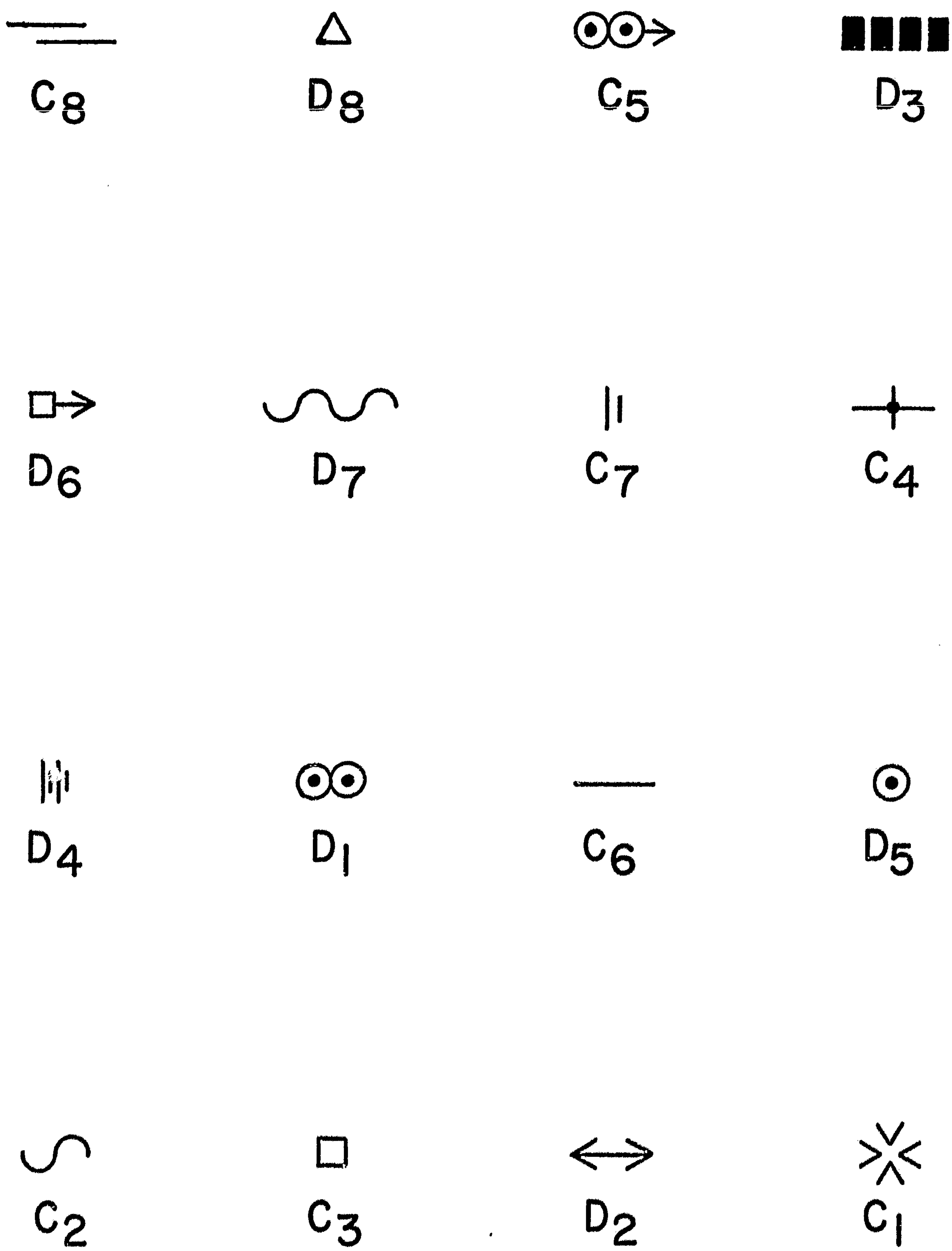
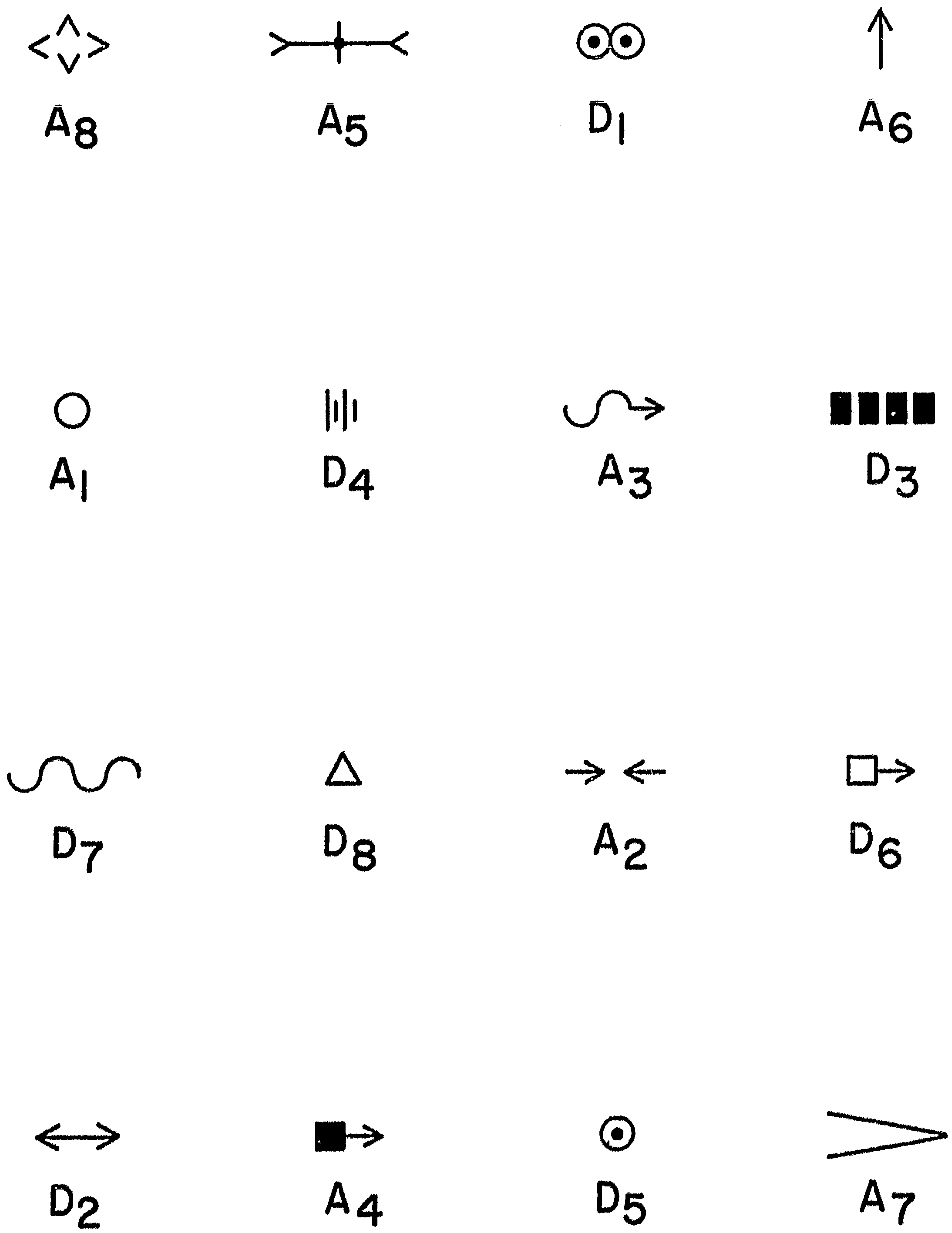


Table VII

D-A

(USE B-D CHECKERS)



dents should be informed that when properly matched, only half (8) of the symbols on the board will be covered. They should be asked to raise their hands when they have completed the task.

The administrator should record the time when the first student finishes; and then record subsequent "completions" at one-minute intervals until all students have finished. The times of completion (to the nearest minute) can be recorded on the score sheets provided.

When all students are finished, the administrator should check each student's board to determine which symbols have been matched correctly. It should be noted that if properly completed, only <u>red</u> checkers will appear on the A-B checkerboards. A quick check with the A-B keyboard provided will indicate whether or not the student has matched the correct symbols.

It is requested that the administrator note the <u>total number</u> of correct responses made by each student on the appropriate score sheet. <u>In addition, it is requested that he place a check or mark in the appropriate square on the key card each time a symbol is missed by a student</u>.

3. After the testing with the A-B boards, the administrator should collect these checkerboards and distribute the C-D boards to the students (C-D boards have yellow borders). The testing procedure should then be repeated as with the A-C boards. This time, however, if all symbols are matched correctly, only <u>black</u> checkers will appear on the boards. The same recordings should be made as with the A-B boards.

4. At this point, all materials, both boards and checkers, should be collected. (If desired, the testing can be terminated at this point and continued at a later sitting.) Then, each student should be given a set of "B-D" checkers. As previously, students should be instructed to remove the checkers from the boxes, spread them out in front of them, with the notches pointing away from them.

The B-C checkerboards (with blue borders) should then be distributed, the the testing procedure, as outlined above, should be repeated. (If properly matched, only <u>red</u> checkers will appear on the board.) Tally results as above.

The B-C checkerboards can be collected, and the D-A boards (with green borders) distributed. In this testing, only <u>black</u> checkers should appear on the board. The usual tabulations should be made.

In order to test "external consistency," some common braille cells were reproduced, including the cells for the letters A, E, I, O, U, X, Y, and Z. Copies of these cells were reproduced on braillon paper using the Thermoform machine. The cells for A, I, U, and Y were arbitrarily labeled X_1, X_3, X_5, and X_7 and were affixed to black checkers. The other four cells were labeled X_2, X_4, X_6, and X_8 and were affixed to red checkers.

Another set of four checkerboards was then prepared on which were arranged A and braille; B and braille; C and braille; and D and braille. Copies of these four boards appear in Tables VIII through XI that follow on pages 31 through 34, respectively. Sets of the boards accompany this report in Exhibit I of the Appendix.

The instructions to the administrator for testing external consistency follow:

<u>Suggestions for the Administration of Part II of the Test</u>:

The purpose of Part II of the test is to determine whether the blind child can "discriminate externally" between the symbols developed for science concepts and braille.

1. For this part, one-half the students can be given sets of A-C checkers, plus a box of <u>red</u> X checkers. These checkers should be arranged in front of the students as with Part I testing. These students should then be given "A and Braille" checkerboards (with black borders). As indicated by the key, if properly matched, only <u>red</u> checkers will appear on this board. The times and numbers correct should be recorded on the sheets provided; symbols missed should be checked on the key.

2. At this time, the remaining students should be given B-D checkers, plus a set of <u>black</u> X checkers. After the checkers are properly arranged in front of the students, each should be given a "D and Braille" checkerboard. When properly matched, only <u>black</u> checkers will appear on the boards. Again, time of completion and the number of correct responses for each student should be recorded on the score sheets. The symbols missed should be checked on the key cards.

3. Following the above two administrations, all materials should be collected.

4. Next, half the students should be given sets of A-C checkers, plus a set of <u>black</u> X checkers. After the checkers are arranged, these students should be given "C and Braille"

Table VIII

A AND BRAILLE

(USE A-C AND X CHECKERS)

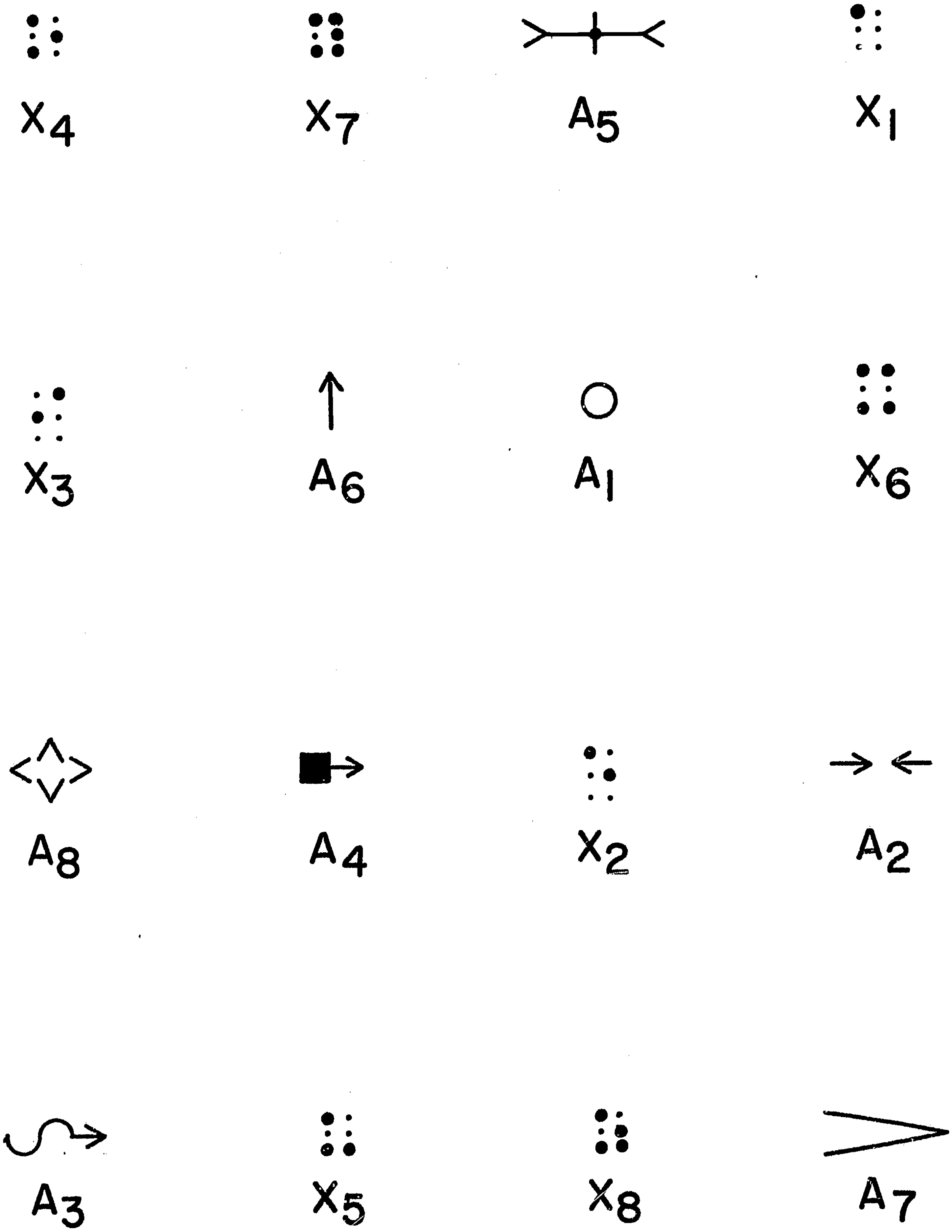


Table IX

B AND BRAILLE

(USE B-D AND X CHECKERS)

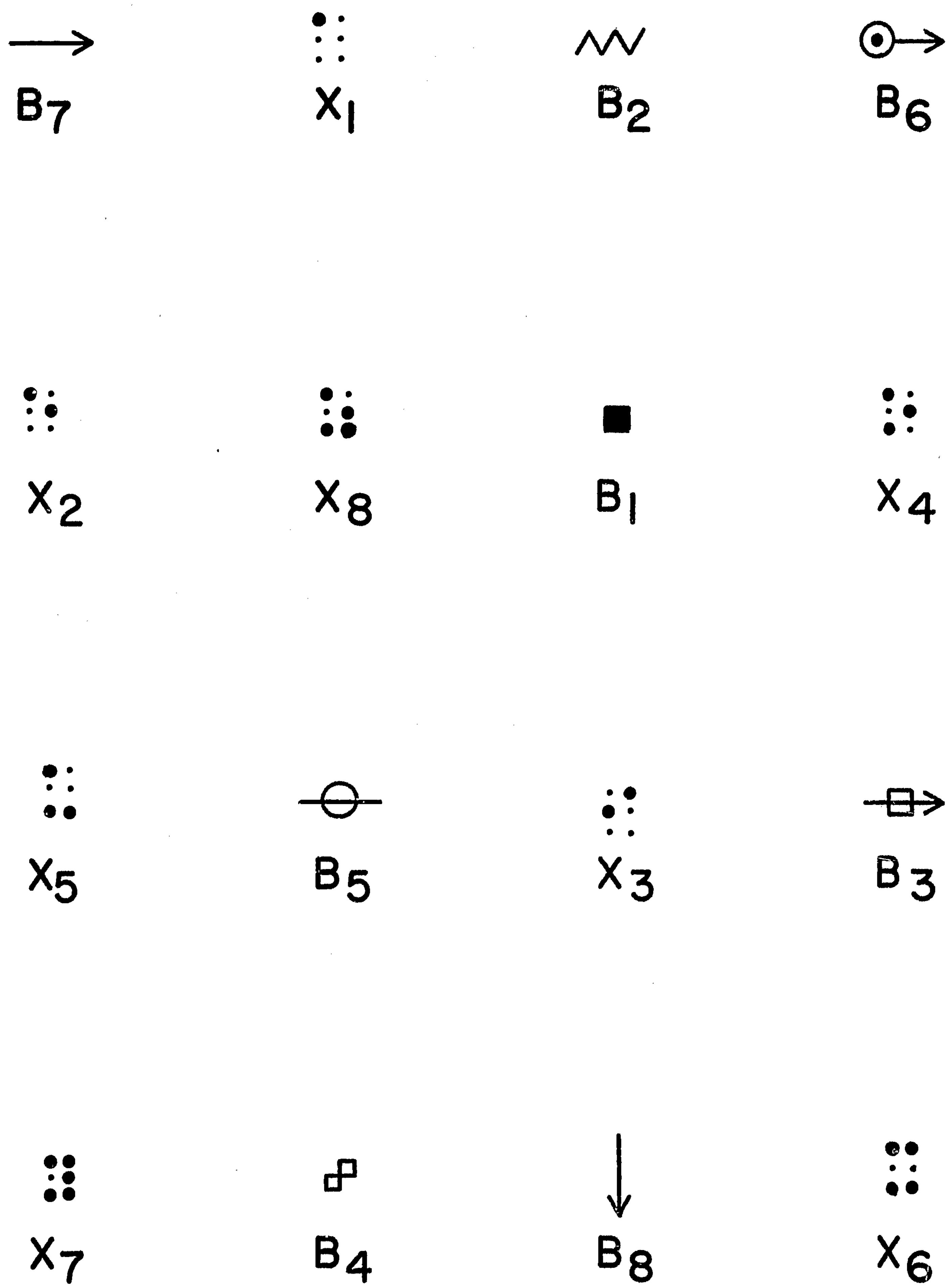


Table X

C AND BRAILLE

(USE A-C AND X CHECKERS)

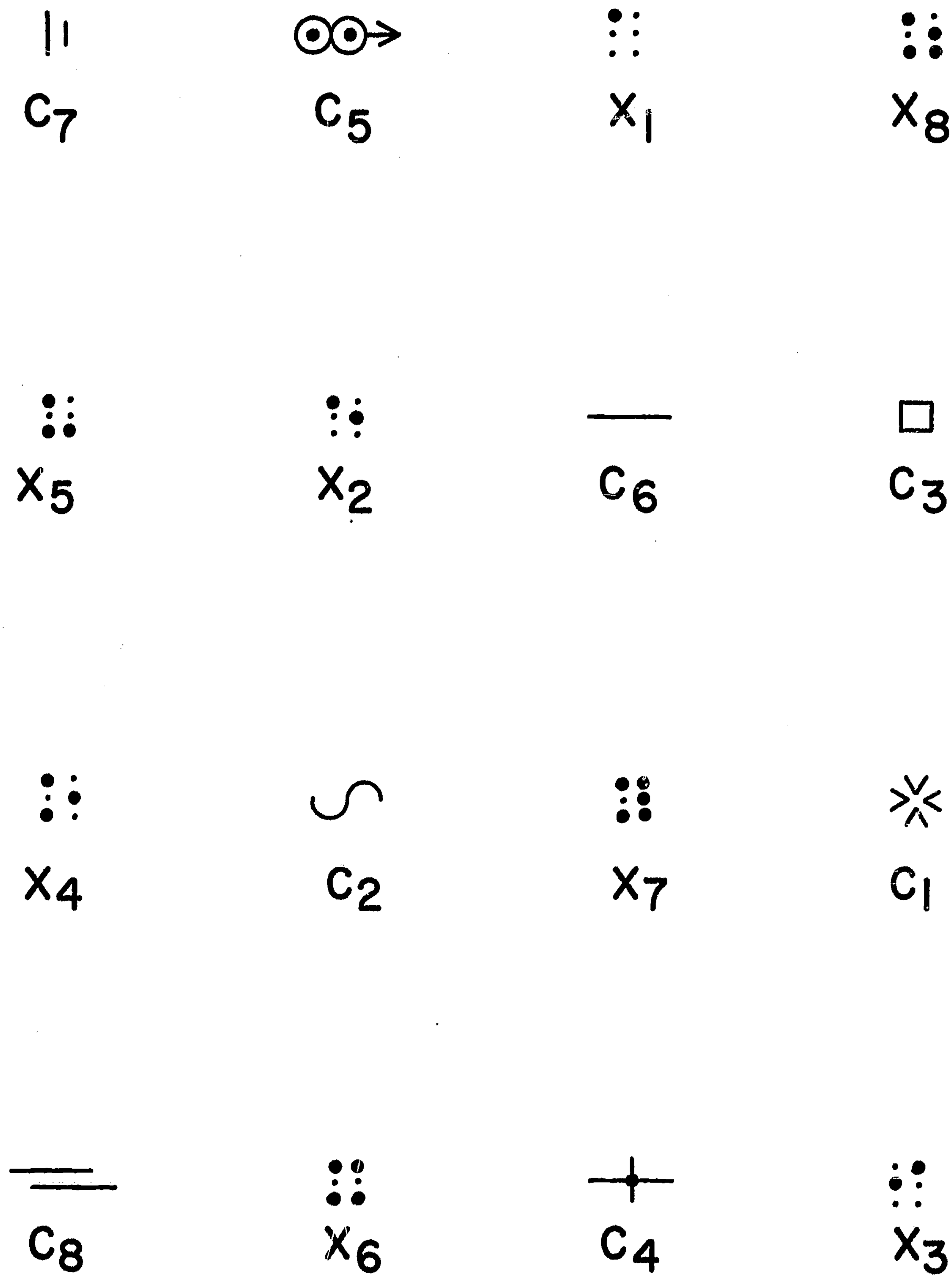
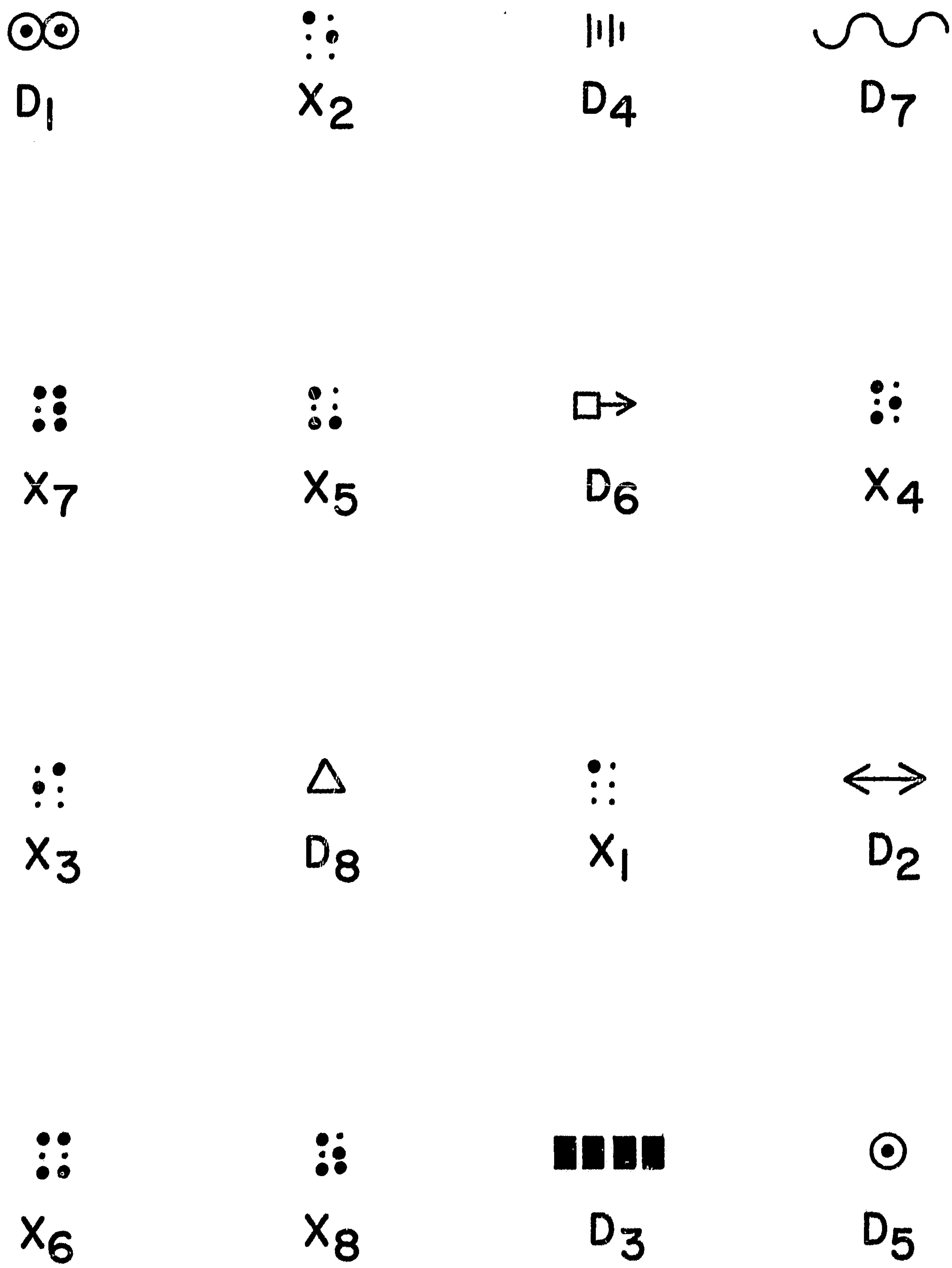


Table XI

D AND BRAILLE

(USE B-D AND X CHECKERS)



checkerboards (black borders). If properly matched, these boards should contain only black checkers. As usual, times and numbers of correct responses should be recorded. Symbols incorrectly matched should be noted on the key cards.

5. The remaining students should be given B-D checkers, plus a box of red X checkers, together with "B and Braille" boards. Correct responses on this board will reveal only red checkers. Make the usual recordings.

The final testing of the symbols, both for internal and external consistency, was conducted with 51 students at the Missouri School for the Blind in St. Louis, Missouri, 43 of whom provided usable results. The administration of the tests was under the direction of Mr. Robert McQuie, Guidance Director at the School. It should be noted that none of the students were aware of the meanings of the symbols. Some of the major findings appear in the chapter that follows.

CHAPTER VI

RESULTS, CONCLUSIONS, AND RECOMMENDATIONS OF PHASE II OF THE STUDY

Purpose

The purpose of this chapter is to discuss the results of Phase II of the study and make recommendations concerning symbolic science learning for the blind.

Results

As indicated in the previous chapter, usable science symbol tests were provided by 43 students enrolled in grades 6-10 at the Missouri School for the Blind. Each child was given two trials on each of the tests. Tables XII through XIX list the ages and I.Q.'s of the students tested, the time required for each to complete the tests, and each student's number of correct responses.

Table XII

RESULTS OF TESTING WITH A-B CHECKERBOARD

Student Data				Trial 1		Trial 2	
Student Number	Age	Grade	I.Q.	Time (Nearest Minute)	Number Correct (out of 8)	Time (Nearest Minute)	Number Correct (out of 8)
1	17	Sp. 9	90	34	5	34	5/7
2	15	Sp. 9	84	25	7	15	8
3	18	10	108	18	8	3	8
4	17	Ung. 9	81	27	3	31	4
5	14	9	105	23	6	14	6
6	16	9	110	30	4	30	6
7	20	Sp. 10	90	20	3	11	5
8	16	10	114	14	4	5	5
9	15	10	123	12	6	2	7
10	15	9	124	16	8	3	8
11	15	10	123	18	6	12	7
12	16	Sp. 9	85	20	3	15	4
13	16	10	93	32	5	26	5
14	16	9	103	5	0	9	2
15	13	7	82	11	8	8	8
16	12	7	115	18	5	13	4
17	17	8	104	10	8	14	6
18	14	7	100	20	2/4	20	1/6
19	13	6	95	15	7	5	7
20	13	7	98	17	6	9	6
21	12	6	112	9	0	6	0

Table XII (continued)

Student Data				Trial 1		Trial 2	
Student Number	Age	Grade	I.Q.	Time (Nearest Minute)	Number Correct (out of 8)	Time (Nearest Minute)	Number Correct (out of 8)
22	11	6	86	10	5	8	6
23	14	8	122	16	7	15	7
24	15	6	96	12	5	14	5
25	12	7	120	10	6	7	6
26	14	8	116	19	7	15	4
27	16	Ung. 8	67	6	2	10	1
28	15	8	94	8	6	3	8
29	14	8	124	15	6/7	20	3/4
30	17	8	77	13	7	9	7
31	16	Sp. 7	89	20	1	20	1
32	15	Sp. 7	100	14	7	6	7
33	15	8	103	12	7	15	8
34	14	6	81	11	0	8	3
35	12	6	139	5	6	4	7
36	18	Ung. 7	64	20	6/10	15	6
37	15	7	107	15	7	6	7
38	12	6	108	8	6	4	5
39	14	7	88	20	5	11	6
40	13	7	104	16	4/7	10	6
41	16	Ung. 7	63	20	2/3	9	3
42	14	8	89	10	6	4	7
43	14	8	102	7	8	4	7

Table XIII

RESULTS OF TESTING WITH B-C CHECKERBOARD

Student Data				Trial 1		Trial 2	
Student Number	Age	Grade	I.Q.	Time (Nearest Minute)	Number Correct (out of 8)	Time (Nearest Minute)	Number Correct (out of 8)
1	17	Sp. 9	90	27	4	15	3
2	15	Sp. 9	84	14	7	11	7
3	18	10	108	4	8	1	8
4	17	Ung. 9	81	23	3	20	1/4
5	14	9	105	22	4	16	4
6	16	9	110	24	1	20	2/6
7	20	Sp. 10	90	23	4	9	3
8	16	10	114	12	8	2	6
9	15	10	123	18	6	10	7
10	15	9	124	3	8	1	8
11	15	10	123	20	6	7	5
12	16	Sp. 9	85	6	2	5	2
13	16	10	93	19	6	13	6
14	16	9	103	7	1	6	1
15	13	7	82	30	6/7	10	7
16	12	7	115	12	3	11	6
17	17	8	104	12	5	12	6
18	14	7	100	11	0	25	1/7
19	13	6	95	23	5	15	7
20	13	7	98	18	3	14	1
21	12	6	112	9	1	7	1

Table XIII (continued)

Student Data				Trial 1		Trial 2	
Student Number	Age	Grade	I.Q.	Time (Nearest Minute)	Number Correct (out of 8)	Time (Nearest Minute)	Number Correct (out of 8)
22	11	6	86	5	7	8	8
23	14	8	122	10	4	8	5
24	15	6	96	22	4	21	3
25	12	7	120	13	6	12	6
26	14	8	116	12	6	16	5
27	16	Ung. 8	67	15	3/10	5	1
28	15	8	94	9	6	10	3
29	14	8	124	19	6/6	15	6/7
30	17	8	77	14	8	6	8
31	16	Sp. 7	89	16	2/6	12	1/7
32	15	Sp. 7	100	14	7	6	7
33	15	8	103	26	4/7	17	5
34	14	6	81	10	1	11	1/9
35	12	6	139	7	7	3	5
36	18	Ung. 7	64	22	1/3	(Put all 16 on the board)	
37	15	7	107	21	7	12	7
38	12	6	108	6	7	8	8
39	14	7	88	18	3/5	15	2/6
40	13	7	104	30	1/5	14	3
41	16	Ung. 7	63	30	1/4	18	3
42	14	8	89	20	5	4	7
43	14	8	102	11	7	6	5

Table XIV

RESULTS OF TESTING WITH C-D CHECKERBOARD

Student Data				Trial 1		Trial 2	
Student Number	Age	Grade	I.Q.	Time (Nearest Minute)	Number Correct (out of 8)	Time (Nearest Minute)	Number Correct (out of 8)
1	17	Sp. 9	90	28	7	5	7
2	15	Sp. 9	84	17	8	10	8
3	18	10	108	1	8	1	8
4	17	Ung. 9	81	16	6	12	6
5	14	9	105	17	8	12	8
6	16	9	110	30	1/7	18	0/2
7	20	Sp. 10	90	18	7	12	7
8	16	10	114	18	7	5	7
9	15	10	123	8	7	3	7
10	15	9	124	5	7	1	7
11	15	10	123	12	7	4	7
12	16	Sp. 9	85	6	2	6	3
13	16	10	93	20	4	9	5
14	16	9	103	8	1	7	1
15	13	7	82	21	8	17	7
16	12	7	115	13	8	9	7
17	17	8	104	9	8	5	8
18	14	7	100	20	1/6	15	2/7
19	13	6	95	9	6	6	7
20	13	7	98	6	7	10	6
21	12	6	112	12	2	10	2

Table XIV (continued)

Student Data				Trial 1		Trial 2	
Student Number	Age	Grade	I.Q.	Time (Nearest Minute)	Number Correct (out of 8)	Time (Nearest Minute)	Number Correct (out of 8)
22	11	6	86	3	7	3	7
23	14	8	122	7	7	5	6
24	15	6	96	20	5/7	16	4
25	12	7	120	14	7	6	7
26	14	8	116	13	7	9	7
27	16	Ung. 8	67	3	1	5	1
28	15	8	94	6	7	6	8
29	14	8	124	20	7/7	15	7
30	17	8	77	9	8	4	8
31	16	Sp. 7	89	20	1	20	1
32	15	Sp. 7	100	8	6/7	4	7
33	15	8	103	13	7	19	7
34	14	6	81	7	1	7	1
35	12	6	139	3	6	2	7
36	18	Ung. 7	64	20	3/5	20	5/6
37	15	7	107	7	6	3	6
38	12	6	108	5	4	5	7
39	14	7	88	7	5	4	5/7
40	13	7	104	20	2/4	8	3/7
41	16	Ung. 7	63	10	2	13	3/7
42	14	8	89	12	6	5	6
43	14	8	102	4	7	5	8

Table XV

RESULTS OF TESTING WITH D-A CHECKERBOARD

Student Data				Trial 1		Trial 2	
Student Number	Age	Grade	I.Q.	Time (Nearest Minute)	Number Correct (out of 8)	Time (Nearest Minute)	Number Correct (out of 8)
1	17	Sp. 9	90	25	2/4	20	5/7
2	15	Sp. 9	84	17	8	7	8
3	18	10	108	4	8	1	8
4	17	Ung. 9	81	24	3	12	3
5	14	9	105	11	6	5	5
6	16	9	110	17	1	22	2/7
7	20	Sp. 10	90	15	4	13	4
8	16	10	114	13	8	3	8
9	15	10	123	6	8	4	8
10	15	9	124	3	8	1	8
11	15	10	123	12	7	6	7
12	16	Sp. 9	85	5	2	5	2
13	16	10	93	20	6	13	5
14	16	9	103	12	4	15	1
15	13	7	82	25	6/7	21	5
16	12	7	115	9	6	8	4
17	17	8	104	14	7	10	6
18	14	7	100	18	1	22	1
19	13	6	95	7	6	3	6
20	13	7	98	10	3	12	4
21	12	6	112	7	0	6	3

Table XV (continued)

Student Data				Trial 1		Trial 2	
Student Number	Age	Grade	I.Q.	Time (Nearest Minute)	Number Correct (out of 8)	Time (Nearest Minute)	Number Correct (out of 8)
22	11	6	86	6	7	7	7
23	14	8	122	7	6	9	6
24	15	6	96	13	6	14	6
25	12	7	120+	12	7	9	6
26	14	8	116	16	4	9	6
27	16	Ung. 8	67	5	0	5	0/7
28	15	8	94	5	7	3	7
29	14	8	124	19	7	13	7
30	17	8	77	5	8	3	8
31	16	Sp. 7	89	20	1/9	9	1
32	15	Sp. 7	100	7	8	9	7
33	15	8	103	15	7	6	5
34	14	6	81	19	3	17	5
35	12	6	139	4	8	3	8
36	18	Ung. 7	64	8	4/5	12	5/6
37	15	7	107	9	7	5	7
38	12	6	108	6	5	5	7
39	14	7	88	18	5	7	4
40	13	7	104	13	4	5	5
41	16	Ung. 7	63	30	0/3	14	1
42	14	8	89	7	7	7	6
43	14	8	102	4	7	2	7

Table XVI

RESULTS OF TESTING WITH A AND BRAILLE CHECKERBOARD

Student Data				Trial 1		Trial 2	
Student Number	Age	Grade	I.Q.	Time (Nearest Minute)	Number Correct (out of 12)	Time (Nearest Minute)	Number Correct (out of 12)
1	14	7	100	28	5/9	45	4/9
2	13	6	95	10	11	6	12
3	14	8	122	8	11	12	11
4	16	Ung. 8	67	19	2	8	3/11
5	15	Sp. 7	100	14	12	11	12
6	15	8	103	19	10	20	10/11
7	15	7	107	10	11	5	11
8	12	6	108	7	12	7	12
9	14	7	88	13	9	7	10
10	16	Ung. 7	63	30	1/5	20	0
11	14	8	89	10	10	5	10/11
12	14	8	102	13	12	4	12

Table XVII

RESULTS OF TESTING WITH B AND BRAILLE CHECKERBOARD

Student Data				Trial 1		Trial 2	
Student Number	Age	Grade	I.Q.	Time (Nearest Minute)	Number Correct (out of 12)	Time (Nearest Minute)	Number Correct (out of 12)
1	15	Sp. 9	84	15	12	7	12
2	18	10	108	10	12	2	12
3	14	9	105	24	10	11	9
4	16	9	110	36	8	27	6
5	15	10	123	13	12	6	12
6	16	Sp. 9	85	9	5	6	3
7	16	10	93	33	11	23	12
8	13	7	98	15	8	22	9
9	11	6	86	11	12	7	12
10	14	8	116	27	10	19	10

Table XVIII

RESULTS OF TESTING WITH C AND BRAILLE CHECKERBOARD

Student Data				Trial 1		Trial 2	
Student Number	Age	Grade	I.Q.	Time (Nearest Minute)	Number Correct (out of 12)	Time (Nearest Minute)	Number Correct (out of 12)
1	17	Sp. 9	90	38	11/11	26	10
2	17	Ung. 9	81	34	9/11	38	7/10
3	20	Sp. 10	90	18	9	13	9
4	16	10	114	4	12	2	12
5	15	9	124	2	12	1	12
6	15	10	123	14	12	3	12
7	16	9	103	37	9/11	17	5
8	13	7	82	9	12	6	12
9	12	6	112	10	1	5	4
10	12	7	120+	16	12	6	12

Table XIX

RESULTS OF TESTING WITH D AND BRAILLE CHECKERBOARD

Student Data				Trial 1		Trial 2	
Student Number	Age	Grade	I.Q.	Time (Nearest Minute)	Number Correct (out of 12)	Time (Nearest Minute)	Number Correct (out of 12)
1	15	8	94	5	12	4	12
2	14	8	124	27	11/11	8	10
3	17	8	77	6	12	5	12
4	16	Sp. 7	89	10	1	7	2
5	14	6	81	18	10	5	11
6	12	6	139	8	10	4	12
7	18	Ung. 7	64	21	6	10	8/9
8	13	7	104	19	10	8	9
9	12	7	115	25	10/11	9	9/11
10	17	8	104	13	12	11	12
11	15	6	96	21	9	22	9

An examination of the tables preceding indicates the following:

1. There appears to be a high degree of relationship between I.Q. and performance on the testing with the checkers and checkerboards. The greatest number of errors in discrimination were made by students with I.Q.'s below 90, although it should be noted that the lowest I.Q. was 80. Students with I.Q.'s above 95 had little difficulty with the tests.

2. There appears to be some relationship between the age (grade level) of the student and his performance. Although the symbols were developed primarily for students at the junior-high-school level, they were also administered to sixth-grade students and senior-high-school students, as a control. It was found that sixth-graders, even those with high I.Q.'s did not perform so well as "average" students of the junior-high-school level.

Interestingly enough, most of the high-school students reacted negatively to the test of discrimination, about half refusing to complete the task.

3. Practice improves performance on the tests, as evidenced by the results of two trials. In almost every case, the second trial was completed in less than half the time of the first. In addition, in most cases there was a marked decrease in the number of errors between the first and second trials.

In addition to the information in the preceding tables, the test administrator provided extensive narrative information concerning the medical and psychological backgrounds of the subjects, as well as information about their personality characteristics. These materials are too extensive to report here. Suffice to say, however, there was a high degree of relationship between the emotional stability of the student and performance on the tests of discrimination. Students who, according to psychological reports, were among those better adjusted to blindness had little difficulty with the tests. Those who were unusually immature or emotionally unstable were not able to "stick with" the tasks.

The test administrator recorded the kinds of errors made by the students. For example, a notation was made of the "checkers" used to cover a symbol whenever the students failed to make a correct match. An examination of this information indicates the following:

1.a. On the first trial the following symbols were missed most frequently:

A_1, A_4, A_6, A_8

B_1, B_2, B_3, B_4, B_6, B_7, B_8

C_1, C_2, C_3, C_5, C_7

D_4, D_5

1.b. On the second trial the symbols missed most frequently were these:

A_1, A_4, A_6

B_1, B_2, B_6, B_7, B_8

C_1, C_5

D_4, D_5, D_8

2. As stated earlier, the symbols were assigned to groups A, B, C, and D at random. Hence, it is likely that there were more symbols in set B than in set D that were difficult to recognize tactually.

3. A final analysis of the test results revealed only one serious problem of discrimination, namely, distinguishing between symbols A_1 and D_5. A visual analysis of these two symbols reveals the reason for the confusion. A_1 is $\bigcirc$; D_5 is $\odot$. Hence, the symbol for one of the terms will need to be modified.

Discussion and Recommendations

In so far as the techniques in this study may be defensible, the following conclusions seem justified:

1. Average students, namely, those with I.Q.'s of 90 or higher, even without knowledge of their meanings, could discriminate among practically all the science symbols and between the symbols and braille. The few exceptions could be rationalized by an examination of the symbols in question and modifications do not seem to be a difficulty. Thus, there does not seem to be a need for replicating this study. Rather, it seems desirable to move forward.

2. The symbols in all cases take up significantly less space than braille cells for the science terms used in this study. Thus, the bulk of braille textbooks for science may be reduced, to an extent as yet unknown, by use of the symbols.

3. The next step in research seems to be the translation of modern science materials for the junior-high school into braille, using the symbols wherever possible. These should be tested on blind junior-high-school students in a classroom, rather than in an experimental situation.

4. There are many technical problems to be solved in instituting such a system but the greatest is likely to be traditional thinking. None of the problems that are evident, or are likely to arise, seem insurmountable. Hence, the use of the symbolic technique for partially replacing braille seems to merit further sequential research.

CHAPTER VII

SUMMARY

Purpose of the Chapter

The purpose of this chapter is to give a brief summary of the purposes, methods, results, and recommendations of this two-phase study concerning the teaching of blind students at the junior-high-school level.

Phase I of the Study

Because of the problems attending their blindness, the instruction of blind students requires far more teacher time and effort than is the case in the instruction of sighted children. Primary teaching activities can be handled on a small-group basis with these students, with classes of as many as 15 students. However, vast amounts of time are required to check the work of blind students, since it is done traditionally on a one-to-one basis. Hence, it was postulated that if a technique of programmed instruction suitable for evaluating the work of blind students could be developed, the teacher might be able to work with greater numbers of students in the same amount of time.

In order to test this postulate, four types of stimulus-response modes for programmed instruction were developed. They were as follows:

1. Audio stimulus - audio response
2. Audio stimulus - braille response
3. Braille stimulus - audio response
4. Braille stimulus - braille response

A pilot testing program revealed that all first three modes were too complex and difficult for students to follow. Hence, a braille stimulus - braille response mode was chosen. An effort was then made to determine the most usable braille stimulus - braille response format that might be used with blind students. The four following formats were designed and tested:

1. A "teaching machine" in which the student read the frames in braille, and responded with a braille slate and stylus on a roll of adding machine tape to the right of the frames.

2. A sheet containing two or three braille frames, with the correct responses covered by a "fold-over" along the right-hand edge of the page. The student recorded his response on the fold-over, with a braille slate and stylus.

3. A sheet containing one frame of braille material, with the correct response covered by a "fold-up" at the bottom of the page, on which the student recorded his response with a braille slate and stylus.

4. A booklet in which the braille frame appeared on one page, the correct response on the next; the student responded using a braille writer or a braille slate and stylus.

The first of these braille-braille modes was discarded because it was cumbersome and required much manual dexterity to operate. The next two were discarded because the materials were expendable and because many students were not adept with a braille slate and stylus, preferring to use a braille writer. Hence, the fourth of these braille-braille formats was used in the final testing.

For both the pilot testing and the final testing, commercially-developed programs for junior-high-school science, developed by TMI-Grolier, were modified for use with blind students. The junior-high-school age group was selected for this study for several reasons:

1. It was believed that this group was mature enough to follow the instructions, but not yet as stereotyped in their learning behavior as high-school students.

2. All these subjects probably had mastered grade-two braille.

3. The Director had much experience working with this age group.

The final tests were administered to students at the Missouri School for the Blind, the Illinois Braille and Sight-Saving School, and the Michigan State School for the Blind. In the final testing, it was found that students of the age level studied could handle programmed materials presented in the final format outlined above. Hence, it was concluded that this technique might have some possibilities for use in evaluating the work of blind students, allowing them to test their own achievement and become aware of their errors. This, in turn, would enable the teacher to spend more time on primary learning activities.

Phase II of the Study

During the first phase of this study, the problems encountered in translating programmed materials designed for sighted students into braille was the bulk of the product. In general, one page of ink-print produces three or more pages of braille. The products are cumbersome for students to handle.

It was noted, also, that many scientific terms were repeated frequently in the programmed science units used. These terms are also used frequently in textbooks, tradebooks, and examinations in science. Hence, it was thought that if some simple, meaningful symbols were developed for the scientific terms appearing most frequently, the bulk of braille materials might be reduced. For example, instead of brailling a term such as "Law of Universal Gravitation," a single, simple symbol to represent the term would save much space.

Hence, a search was made of all leading science textbooks, and other related learning materials designed for students in junior-high-school general science. The terms appearing most frequently were thus identified, and appropriate symbols were developed. It should be noted that an attempt was made to make each symbol empirically logical; that is, it must not be merely a "nonsense" symbol, but must carry with it meaning. The initial list was tested and certain terms and symbols were eliminated. The final list consisted of 32 terms and corollary symbols.

It was then necessary to determine whether blind students could discriminate among the symbols (internal consistency), and between the symbols and braille (external consistency). To check discrimination, sets of "checkers" and "checkerboards" containing the various symbols were developed. Blind students at the Missouri School for the Blind, grades 6-10 were tested. They were requested to place "checkers," containing either a science symbol or a braille cell, on matching squares on eight different "checkerboards." The accuracy with which they completed the tasks was an index of these consistencies.

It was found that students had only moderate difficulty in distinguishing among the various special science symbols. In general, a student's performance was related to his I.Q., the brighter students doing better. Students in the sixth-grade did not do well on the test, presumably because most were not yet proficient in grade-two braille. Likewise, high-school-age students resisted the task and did not do well. Other related studies indicate that high-school-age blind students tend to reject new techniques and methods. Also, students who were less mature or emotionally unstable had difficulty with the task.

Only two symbols were confused by the students tested. They were designated as A_1 ○ and D_5 ⊙ . A visual analysis of these reveals the reason for the confusion. Hence, one will need to be altered. There was no difficulty discriminating among the science symbols and standard braille cells.

From this study, it appears that some symbols might well replace braille for teaching junior-high-school science. The symbols might reduce the bulk of braille books. It is possible, also, that such symbols, since they are empirically sound, might well be used in materials for sighted students.

Appendix

Appendix - Exhibit A

Please see tape enclosed.

Appendix - Exhibit B

20-Frame Braille Program

NDEA Grant No. 7-32-0580-191

Western Michigan University

Kalamazoo, Michigan 49001

Dr. George G. Mallinson, Director

Biology - The Plastids

Directions

The following material is a unit in Biology on "The Plastids." Each statement is numbered and is called a "frame." Each frame has the answer immediately following the question. In this format, frame 1 is at the top of page 1. The question should be read, your answer should be written on the braille writer, the answer line rolled up for easy reading, and the page turned. In the small box at the top of the page will be the answer to frame 1. Frame 2, in a page-wide box, follows immediately after the answer to frame 1.

The frames at the top of the page should be answered until frame 10 is reached. The answer for frame 10 is on the lower half of page 1 and is followed by frame 11. The frames on the lower half of the pages should be answered until frame 20 is reached. The answer for frame 20 is on the last page of the unit.

Frame 1. All living things are made up of cells. All living things contain _______.
cells

Frame 2. _______ are composed of living and non-living
Cells
matter.

Frame 3. Non-living matter in a cell is called <u>the inclusions</u>. All non-living matter in a cell is called _______________.
the inclusions

Frame 4. Living matter in a cell is called plastids. Non-living matter is called inclusions, and living matter is called ________.
plastids

Frame 5. The most common plastid is the chlorophast. It contains a pigment which makes leaves green. Chloroplasts contain chlorophyll, a ________ which makes leaves appear green.
pigment

Frame 6. Chloroplasts contain chlorophyll which is ______ in color.
green

Frame 7. Another plastid found in plant cells is a chromoplast. Chromoplasts contain yellow, orange, and red pigment. Chloroplasts contain ______ pigment.
green

Frame 8. Chromoplasts are found in the cells of flower petals and the skins of fruit.
Chromoplasts are the things that make flowers and fruits colorful. When a flower is yellow, orange, or red, we know its cells contain ____________.
chromoplasts

Frame 9. Green leaves are made up of cells which contain ____________.
chloroplasts

Frame 10. When we say chloroplast, we usually think of the color green.
When we say chromoplast, we probably think of a color such as ____________________.
yellow, red, or orange

Frame 11. ____________ contain green pigment and ____________ contain yellow, orange, or red pigment.
Chloroplasts chromoplasts

Frame 12. The green pigment which is found in chloroplasts is called chlorophyll. This substance does two things. It is necessary for food manufacture and it also gives plants their ______ color.
green

Frame 13. Two of the three common types of plastids found in plant cells are ____________ and ____________.
chloroplasts chromoplasts

Frame 14. The third type is leucoplasts. The three most common types of plastids found in plant cells are ______________, ______________, and leucoplasts.
chloroplasts chromoplasts

Frame 15. Chloroplasts and chromoplasts have color. Leucoplasts are colorless. The ______________ have no color.
leucoplasts

Frame 16. Write leucoplasts - no color five times.

leucoplasts - no color (five times)

Frame 17. Write chloroplasts - green five times.

chloroplasts - green (five times)

Frame 18. Write chromoplasts - red, yellow, orange five times.

chromoplasts - red, yellow, orange (five times)

Frame 19. Leucoplasts usually serve as storage places for food for cells. These colorless plastids are called ______________.
leucoplasts

Frame 20. The three most common plastids found in plant cells are ______________, ______________, and ______________.
chloroplasts chromoplasts leucoplasts

Appendix - Exhibit C

See braille programmed booklets entitled "Plastids."

Appendix - Exhibit D

BOOK I
#45 FRAME BRAILLE PROGRAMS
CHEMICAL SYMBOLS AND CHEMICAL FORMULAE
NDEA Grant No. 7-32-0580-151
WESTERN MICHIGAN UNIVERSITY
KALAMAZOO, MICHIGAN

DR. GEORGE G. MALLINSON, DIRECTOR

Chemistry - Unit Three - "Symbols and Formulae"

Book I - Acknowledgments

The Director of this project wishes to acknowledge the efforts of Mrs. David Jackson of 7217 South Crandon, Chicago, Illinois, who used the Johanna Bureau of the Blind, and the City of Chicago Library for reproducing Books I and II. Special acknowledgement is also given to The Grolier Society for permission to reproduce these materials from the TMI-Grolier Programmed Textbook: General Science - Biology and Chemistry, Volume 1 of 2 and Volume 2 of 2.

The Director wishes to acknowledge the indispensable effort of Miss Ellen Van Vliet, Resource Teacher for the Blind, Roosevelt School, Cicero, Illinois, for various types of work in preparation of the braille programs. Credit is also due Mr. George J. Ossentjuk and Miss Frances Crawford for reviewing the programs prior to publication.

George G. Mallinson
Project Director

Book I - #45 Frame Braille Programs - "Chemical Symbols and Chemical Formulae"

Book I

These are chemistry lessons in a new kind of book called a programmed textbook. The lessons are about chemical symbols and chemical formulae; and about physical changes and chemical changes. The lessons are arranged in sections called frames. You will work with two booklets; the first one has 45 double frames, and the second one, 50 double frames. The first part of the double frame gives information about the chemistry topic and then asks a question. The correct answer is on the following page in the second part of the double frame in a small box. You are to read the first part of the frame and then answer the questions on either the braille writer or slate. Then turn to the small box on the next page and see whether your answer is the same as the correct one.

Here is an example of the way you will work. At the top of the first page there is a large boxed-in frame that looks like this:

Frame 1. The names of elements can be written in a short form called <u>symbols</u>.
For example, oxygen can be writted as O (capital letter). The ________ for oxygen is <u>O</u>.
symbol

Answer the question by writing the correct word on your braille writer or slate. Then roll up the paper so you can read it easily and turn to page 2. At the top of page 2 there are two boxes, a small one above a larger one. The correct answer to the question on page 1 is in the smaller box. The information and question for frame 2 is in the larger box just below it. For example:

Frame 2. The symbol for hydrogen is <u>H</u>. Thus we can represent __________ by the symbol <u>H</u>.
hydrogen

If your answer to frame 1 is the same as the answer in the smaller box, go to the larger frame just below. If your answer is not the same, turn back one page and read the first part of the frame again until you understand the right answer. When you have written your answer to frame 2, turn to the next page to find the correct answer at the top. Keep working this way on the <u>upper half</u> of the pages.

Book I - #45 Frame Braille Programs - "Chemical Symbols and Chemical Formulae"

Book I (continued)

When you come to frame 23 and have written the answer, turn all the way back to page 1. The answer to frame 23 will be in the small box in the middle of page 1. Frame 24 is just below. Keep working on the bottom half of the pages until you complete frame 45.

You will work with Book II on "Physical and Chemical Changes" in the next book the same way as you worked with this one.

CHEMISTRY
UNIT THREE
"Symbols and Formulae"

Frame 1. The names of elements can be written in a short form called symbols. For example, oxygen can be written as O (capital letter). The ________ for oxygen is O.
symbol

Frame 2. The symbol for hydrogen is H. Thus we can represent ________ by the symbol H.
hydrogen

Frame 3. Science books usually contain a list of the 92 natural ________ and their symbols.
elements

Frame 4. Each element has a different symbol. We have 92 symbols, ___ symbol for each element.
1

Frame 5. All symbols begin with a capital letter. Some symbols have two letters with the first one a capital. The symbol for calcium is Ca. The symbol for oxygen is its first letter. The symbol for oxygen is written ___.
O

Frame 6. Hydrogen's symbol is its first letter. The symbol for hydrogen is ___.
H

Book I - #45 Frame Braille Programs - "Chemical Symbols and Chemical Formulae"

Book I (continued)

Frame 7. The second letter (if there is one) of a symbol is a small letter. The symbol for calcium is its first two letters. It is written ____.
Ca

Frame 8. Ca, Fe, Au are symbols for elements. In the symbols for elements the _______ letter is always a capital;
first
the ________ letter is always a small letter.
second

Frame 9. The symbol for the element cobalt is the first two letters of its name. Its symbol is ____.
Co

Frame 10. The symbol for carbon is its first letter. Its symbol is written ___.
C

Frame 11. Compounds are made of elements. Therefore, the names of compounds can be written in the symbols of these __________.
elements

Frame 12. CO is a compound made of carbon (C) and oxygen (O). H_2O is a compound made of hydrogen (H) and ____________.
oxygen (O)

Frame 13. To find the number of elements in a compound, count the number of capital letters.
How many capital letters or elements are in this one: $CaCO_3$? ___
3

Frame 14. How many different elements are in the compound $CaCl_2$? ___
2
How many in Cu? ___
1

Frame 15. When a compound is written in symbols it is called a formula.
H_2O is the ________ for water.
formula

Book I - #45 Frame Braille Programs - "Chemical Symbols and Chemical Formulae"

Book I (continued)

Frame 16. $CaCl_2$ is the formula for a compound because it shows more than one element. H_2O is the ________ for the compound water.
formula

Frame 17. $CaCl_2$ is a formula for a compound containing _____ different elements.
two
Ca is a symbol for one element.
Cl is a ________ for the other element.
symbol

Frame 18. A symbol represents an element.
A ________ represents a compound or combination of elements.
formula

Frame 19. $CaCO_3$ is a ________ because it shows _______ different elements present.
formula three

Frame 20. A formula is a short way of writing the name of a compound.
A symbol, however, represents a(n) ________.
element

Frame 21. Some formulae contain numbers. CO_2 shows us that this compound contains 1 part carbon to 2 parts oxygen. We know there are 2 parts oxygen because of the number ___ next to and beneath the O.
2

Frame 22. The numbers in a formula show how much of each element is in the compound.
H_2O shows that in this formula there are 2 parts H and 1 part O.
$CaCl_2$ shows ___ part(s) Ca and ___ part(s) Cl.
1 2

Frame 23. CO_2 shows ___ part(s) C and ___ part(s) O.
1 2

Frame 24. A chemist could make a compound by combining the elements in the correct amounts as shown in the ________ of the compound.
formula

Book I - #45 Frame Braille Programs - "Chemical Symbols and Chemical Formulae"

Book I (continued)

Frame 25. A symbol is the short way to write the name of an element.
A ________ is the short way to write the name of a
formula
compound.

Frame 26. ________ are short ways to write the names of
Symbols
elements.

Frame 27. The symbols for elements always begin with ________ letters.
capital

Frame 28. These two materials, Fe and Cu, each are ________.
elements

Frame 29. These materials, H_2O and CO_2, are ________ because
compounds
each is made of more than one ________.
element

Frame 30. The number 2 tells us that there are 2 parts hydrogen in H_2O.
The ________ 2 tells us that there are 2 parts chlorine
number
(Cl) in $CaCl_2$.

Frame 31. The various ________ beneath the symbols of a formula
numbers
tell us how much of that element is in the compound.

Frame 32. The numbers always follow the symbol to which they belong, thus, CCl_2, not C_2Cl.
Water is 2 parts hydrogen (H) and 1 part oxygen (O).
Its formula is _____.
H_2O

Frame 33. The numbers are read as they come H_2O is read H-Two-O.
Write H_2O five times and pronounce it out loud.

____
H_2O (five times)

Book I (continued)

Frame 34. Notice that the numbers are always written half a line below the letter.
The formula for water, 2 parts hydrogen (H) and 1 part oxygen (O), is correctly written _____.
H_2O

Frame 35. If there is only one part of an element in a compound the number 1 is never written. In H_2O, for example, the fact that there are 2 parts H is shown by the figure 2; but the fact that there is only 1 part O ________ specially shown by a figure.
is not

Frame 36. One could, of course, write H_2O_1, but it is never done that way.
The correct way to write the formula for water is _____.
H_2O

Frame 37. If someone writes Na_1Cl_1 he is not doing it correctly. The 1 is never written.
The correct way to write the above formula is ______.
NaCl

Frame 38. Salt is 1 part sodium (Na) and 1 part chlorine (Cl). Its formula is ______.
NaCl

Frame 39. Iron ore is 2 parts iron (Fe) and 3 parts oxygen (O). Its formula is _______.
Fe_2O_3

Frame 40. Fe_2O_3 is read F-e-2-O-3. Write Fe_2O_3 five times and pronounce it to yourself.

____
Fe_2O_3 (five times)

Frame 41. Sulfuric acid is made of 2 parts hydrogen (H), 1 part sulfur (S), and 4 parts oxygen (O). Its formula is

________.
H_2SO_4

Frame 42. H_2SO_4 is read H-2-S-O-4. Write H_2SO_4 five times and say it to yourself.

____
H_2SO_4 (five times)

Book I - #45 Frame Braille Programs - "Chemical Symbols and Chemical Formulae"

Book I (continued)

Frame 43. Every material that takes up space and has weight is called matter.
All matter takes up ______ and has ________.
space weight

Frame 44. Every material represented by a symbol is a form of ________.
matter

Frame 45. Every material represented by a formula is a form of ________.
matter

Appendix - Exhibit E

See braille programmed booklets entitled "Chemical Symbols and Chemical Formulae."

Appendix - Exhibit F

BOOK II
#50 FRAME BRAILLE PROGRAMS
PHYSICAL AND CHEMICAL CHANGES
NDEA Grant No. 7-32-0580-151
WESTERN MICHIGAN UNIVERSITY
KALAMAZOO, MICHIGAN

DR. GEORGE G. MALLINSON, DIRECTOR

Chemistry - Unit Four - "Physical and Chemical Changes"

Book II

Book II, "Physical and Chemical Changes," should be worked in the same way as directed in Book I, "Chemical Symbols and Chemical Formulae." Below the 50 frames are reproduced.

CHEMISTRY
UNIT FOUR
"Physical and Chemical Changes"

Frame 1. Matter can be changed in two ways - physically and chemically. A physical change affects the form, shape or state of matter, not its composition. If you break glass, it is still glass. You have made a ________ ________ in the glass. physical change

Frame 2. Tearing a piece of paper into small bits changes only the <u>size</u> and <u>shape</u> of the paper. Therefore, tearing paper is a ________ change. physical

Frame 3. Physical changes <u>do</u> <u>not</u> produce new compounds. Melting ice (solid water) is a ________ change physical because the water is still H_2O.

Book II (continued)

Frame 4. A change in the state of matter is a physical change. Water turning into steam is a ________ change because it is still H_2O.
physical

Frame 5. A change of state from solid to liquid is a ________ change.
physical

Frame 6. Compounds cannot be formed by a physical change. Sugar is a compound; therefore, sugar cannot be formed by a ________ change.
physical

Frame 7. Combining hydrogen and oxygen to form H_2O is not a physical change, but rather it is a ________ change.
chemical

Frame 8. Melting ice is a physical change. The actual making of water from hydrogen and oxygen is a ________ change.
chemical

Frame 9. Only the state of matter (gas, liquid, solid) or the appearance (shape) of matter is changed in a ________ change.
physical

Frame 10. Chemical changes form new products. These changes either form new compounds or break up compounds. Combining hydrogen and oxygen to form water is a ________ change because a compound is formed.
chemical

Frame 11. No new products are formed when a pencil is broken. Breaking a pencil ________ a chemical change.
is not

Frame 12. When ice is melted and becomes water, it continues to be H_2O. This is not a chemical change, but rather it is a ________ change.
physical

Frame 13. When the separate elements hydrogen and oxygen are combined to form water, (H_2O), a new compound is formed. This is a ________ change.
chemical

Book II - #50 Frame Braille Programs - "Physical and Chemical Changes"

Book II (continued)

Frame 14. Here is a case where you still have the same substance. First you have wood; then you grind it up; then you have sawdust. The grinding up was a ________ change.
physical

Frame 15. Now, here is a case where you have a new product. First you have wood; then you burn it; then you have ashes. Burning was a ________ change.
chemical

Frame 16. When compounds are formed, elements must undergo a ________ change.
chemical

Frame 17. Water and ice are both H_2O. Changing water into ice changes only the water's appearance and state. This is a ________ change.
physical

Frame 18. Chemically, compounds are different from the products from which they are made. All compounds, then, are a result of ________ changes.
chemical

Frame 19. Mixtures are not new or different products. Mixtures are formed by ________ changes.
physical

Frame 20. A mixture is formed by a ________ change.
physical
A compound is formed by a ________ change.
chemical

Frame 21. Combining sand with water forms a mixture (no new product is formed). This mixture is produced by a ________ change.
physical

Frame 22. Compounds are produced by ________ changes; mixtures
chemical
are produced by ________ changes.
physical

Book II (continued)

Frame 23. Chopping wood with an axe is a ________ change
physical
because the log only changes in appearance (it is still wood).

Frame 24. Baking a cake produces a ________ change because
chemical
new compounds are formed.

Frame 25. Burning a log is a ________ change because new
chemical
products (ashes) are formed.

Frame 26. Melting is a ________ change because ____ new pro-
physical no
duct is formed.

Frame 27. ________ changes produce new products; ________
Chemical physical
changes do not.

Frame 28. Chemical changes are also called chemical reactions. Burning gas is a chemical change. It is also called a chemical ________.
reaction

Frame 29. Chemical reactions (since they are chemical changes) produce new products. All compounds are the result of ________ reactions.
chemical

Frame 30. Another chemical change is baking a cake. This is an example of a chemical ________.
reaction

Frame 31. The process of separating a compound into its parts is also a chemical reaction. The release of hydrogen and oxygen from water (a compound) is the result of a

________ ________.
chemical reaction

Frame 32. Separation of a metal from its ore (a compound) is an example of a chemical ________.
reaction
(or change)

Book II (continued)

Frame 33. The combination of two or more elements to form a compound is called a _______ _______.
chemical reaction
(or chemical change)

Frame 34. Chemical reactions produce _______ changes in matter.
chemical

Frame 35. In all chemical reactions _______ are formed from elements or separated into elements.
compounds

Frame 36. In all chemical reactions energy is present. In order to have a reaction we must have some form of _______.
energy

Frame 37. In some reactions energy is added; in others energy is given off. In any chemical reaction, however, we must have _______ present.
energy

Frame 38. Burning is a chemical reaction in which _______ is given off or released.
energy

Frame 39. Chemical reactions which give off energy can be useful. We use heat energy from burning gas to warm our homes. Chemical _______ then can produce useful energy.
reactions
(or change)

Frame 40. The heat energy (produced by burning coal) which melts iron in a blast furnace is the result of a chemical _______.
reaction
(or change)

Frame 41. A chemical reaction which produces heat and light, or radiant energy, is called combustion. Burning wood is an example of a chemical reaction called _______.
combustion

Book II (continued)

Frame 42. A combustion is a chemical _________ which produces heat and light.
reaction
(or change)

Frame 43. All chemical reactions either use or give off some form of ________.
energy

Frame 44. Some reactions don't give off energy, but need it in order to complete the reaction. In baking a cake we add heat energy to complete the _________.
reaction
(or chemical reaction)

Frame 45. In some reactions energy is both added and given off. We light a match to start a fire and the fire then produces ______ to warm us.
heat
(or heat energy)

Frame 46. Lightning (electric energy) can start a fire which produces ______ and light.
heat
(or heat energy)

Frame 47. In all chemical reactions some type of ________ is present.
energy

Frame 48. Much of our useful energy is given off during a chemical _________.
reaction

Frame 49. Burning gasoline in autos and burning gas in a furnace are examples of useful ________ released by chemical reactions.
energy
(or heat)

Frame 50. Energy is present in all chemical reactions. In order to bake a cake or cook a steak (chemical reactions) we must use some form of ________.
energy

Appendix - Exhibit G

See braille programmed booklets entitled "Physical and Chemical Changes."

Appendix - Exhibit H

See sets of braille checkers.

Appendix - Exhibit I

See sets of braille checkerboards.