R E P O R T R ' S U M E S

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THREE METHODS OF PROCESSING STUDENT RESPONSE DATA IN PROGRAMED INSTRUCTION. COMPARATIVE STUDIES OF PRINCIPLES FOR PROGRAMMING MATHEMATICS IN AUTOMATED INSTRUCTION, TECHNICAL REPORT NO. 7.

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WORKSHEETS FROM AN AUTO-INSTRUCTIONAL PROGRAM IN HIGH SCHOOL ALGEBRA WERE USED TO COMPARE DATA PROCESSING METHODS. IN THE SCRIBE SYSTEM, WORKSHEET DATA IS TRANSFERRED FIRST ONTO SPECIAL SHEETS REQUIRING RECORDING OF ERRORS AND OMISSIONS ONLY, AND THEN ONTO IBM CARDS. THE IBM CARDS CAN BE USED IN A SPECIAL IBM 1620 ITEM DIFFICULTY ANALYSIS PROGRAM. THE SIMPLE MANUAL METHOD RESULTS IN A "CONDENSED TABULATION SHEET," WHICH HAS THE ADVANTAGES OF IMMEDIATE IMPLEMENTATION AND COMPACT DISPLAY OF LARGE AMOUNTS OF DATA, BUT THE DISADVANTAGE OF MANUAL ROW AND COLUMN COUNTS. THE DIRECT KEYPUNCH METHOD USES THE SAME LAYOUT AND CODING AS THE SCRIBE SYSTEM, BUT THE DATA ARE RECORDED DIRECTLY ONTO IBM CARDS WITHOUT THE INTERVENING SCRIBE SHEET. IN THIS COMPARISON, THE KEYPUNCH METHOD WAS RECOMMENDED, FOLLOWED BY THE CONDENSED TABULATION SHEET METHOD WHEN IBM EQUIPMENT IS NOT AVAILABLE. THE SCRIBE SYSTEM WAS RECOMMENDED ONLY WHEN A KEYPUNCH IS NOT AVAILABLE, DATA VOLUME IS LARGE, AND A TIME LAG IS NOT OBJECTIONABLE. A SAMPLE SCRIBE SHEET, INSTRUCTIONS FOR RECORDING WORKSHEET DATA ON SCRIBE SHEETS, A SAMPLE DISPLAY OF SCRIBE OUTPUT, SAMPLE ITEM ANALYSIS OUTPUT, AND A SAMPLE CONDENSED TABULATION SHEET ARE INCLUDED. (BB)

UNIVERSITY OF ILLINOIS
Urbana, Illinois

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Technical Report No. 7

July, 1964

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OFFICE OF EDUCATION

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Three Methods of Processing Student Response Data in Programed Instruction[1]

Gerald L. Frincke and Lawrence M. Stolurow

The guidelines for making valid and reliable decisions about stimulus control of behavior from data obtained while students are learning are an important but neglected part of educational technology. The research worker concerned with this problem, however, soon becomes aware of the difficulties of reducing large amounts of data. This has led many to argue that the needed guidelines for making the complex decisions required in developing materials with effective stimulus control can be arrived at by rising small samples of students (e.g., Eigen, 1964). The extremes of position concerning sample size are probably rooted in the position taken with regard to the importance and range of individual differences in learning. This paper assumes that individual differences are an important source of variance in learning scores, and that scores vary over a wide enough range to require substantial numbers of students in order to find answers to instructional questions about the stimulus control of behavior.

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1 John Gilpin of the UICSM Mathematics Project developed the second and third methods described in this report and used them to accomplish a number of different analyses. Dr. Paul Jacobs, ETS, assisted in the arrangements made to use the SCRIBE system. The study involving SCRIBE was made possible by the cooperation of Educational Testing Service, Princeton, New Jersey, and the funds made available to them on ETS Project 712, provided under a grant from the Carnegie Corporation of New York.

The fact that large quantities of data will be required needs to be accepted and efficient ways of coping with the problems that they present need to be sought. This report describes three methods of processing student response data obtained from an auto-instructional program in UICSM high school algebra in which students made constructed responses on work sheets. One method uses a partially utomated system consisting of equipment developed for processing test data. The other approaches develop recording systems that facilitate data analysis and decision making while minimizing the equipment requirement. This report describes these methods and summarizes some preliminary data obtained from their use of a common set of data.

FIRST STUDY

Use of the SCRIBE System in Processing Student's Response to Frames of a Mathematics Program

This report describes the use of the Educational Testing Service's SCRIBE system for processing student's responses to frames of programed instructional material in UICSM high school algebra. The basic information was the student's constructed response recorded on worksheets. These are then recorded on a special SCRIBE answer sheet. These answer sheets are used by the SCRIBE system to punch the data they contain onto IBM cards. These cards then can be used to obtain graphic and statistical summaries from a computer.

While there are many different ways in which one might want to process a large number of worksheets obtained from students who respond frequently over a period of hours, some form of automation seems to be required. One place at which automation could be introduced would be in data reduction, another would be in data collection. It is the former phase that is being studied here. The problem is one of concern to both research workers and school administrators. Some data relating to the time requirements and the cost of the work are summarized.

MATERIALS AND PROCEDURES

SCRIBE sheets. Appendix A contains an actual SCRIBE sheet as used in the present project. These sheets must be die-cut and printed to exact specifications for use on the SCRIBE scoring device.

Scoring mask. Use of a single style of SCRIBE sheet for all of the programed parts has been made possible through the use of transcription masks prepared separately for each part to be recorded. This mask, in effect, renumbers the recording boxes on the SCRIBE sheet in accordance with page and problem numbers on the worksheet. The recording of fixed ID information is also facilitated through use of the mask. Mask construction is simple: A light piece of cardboard is first cut to the size of a SCRIBE sheet. Then, half-inch wide slots are cut in the cardboard so that the marking boxes of a SCRIBE sheet placed beneath the mask are exposed. The exposed marking boxes are numbered on the mask to correspond with the desired worksheet page and problem numbers. Openings can be made in the mask over the ID information boxes in such a manner that only the marking boxes needed to record ID information are exposed. The masks thus produced for various worksheets, are quite similar except for the numbering of the marking boxes. Conceivably, they could be mass produced if many different sets of data were to be recorded. Individual fabrication requires 30 to 50 minutes.

Recording data. The data originally recorded by the students on their worksheets were scored and the results recorded on the SCRIBE sheet by blackening the appropriate marking boxes on the sheet with an ordinary pencil. Omits were indicated by blackening one box; errors by blackening a different box; and correct responses require no marking at all. This pattern was used to minimize transcription from worksheet to SCRIBE sheets. Correct responses are generally more frequent than errors on program frames, consequently, much recording time was saved. Sample instructions for clerks recording the data on SCRIBE sheets are presented in Appendix B. Note that the clerks have to work with graded sheets since someone has to judge the correctness of each response. It is these data that are recorded on the cards, not the original responses of the students.

SCRIBE Sheet Processing.

Completed SCRIBE sheets must be sent to Educational Testing Service, Princeton, New Jersey for further processing. Currently, their SCRIBE system records the data from each SCRIBE sheet on 6 IBM cards. Each card is numbered and contains all ID data recorded on the SCRIBE sheet, as well as 60 columns of item data. The item data are coded on the cards as follows: A number one-punch in a column indicates that the item was omitted; a blank column represents a correct response.

Use of SCRIBE output cards. Before processing the data, the IBM cards bearing the information from the SCRIBE sheets must be sorted according to card number. This is done in only a few minutes using an electric card sorting machine. A visual data display can then be obtained by printing

the information from the six card groups obtained by sorting. Interpretation of the printed information can be facilitated by preparing a set of item label IBM cards which simply list the SCRIBE sheet item number above each column to be printed. These cards are made as follows: The first card contains the hundred's digits of the SCRIBE sheet item numbers in the appropriate columns. The second and third cards contain, respectively, the tens and unit's digits of the SCRIBE sheet item numbers in the proper columns. Once made, these cards can be used to label the SCRIBE output data for any programed part. The cards are inserted in the card listing device followed by a deck of cards each bearing the appropriate card number and containing the data of the desired subjects for a given programed part. Visual inspection of the output lists enables one to trace the progress of any individual throughout the program. Items can be identified by observing their SCRIBE sheet item numbers and then referring to the scoring mask and a SCRIBE sheet for indication of the worksheet page and item number. A sample of a graphic display created in the manner given above can be found in Appendix C.

Item difficulty analysis. The SCRIBE output cards can be used to obtain item difficulty data. A program has been written for the IBM 1620[2] which accepts unmodified SCRIBE output cards as data and produces a summary of correct responses, errors, omits, and errors plus omits for each worksheet item. Output may be in the form of IBM cards or a typewritten listing. Appendix D contains a sample output listing. Further statistical analyses of the data can be carried out using either the card output of the item difficulty analysis from the SCRIBE output cards themselves.

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[2]Item Analysis Program. Urbana, Ill.: Univer. of Ill., Training Research Laboratory, 1963.

EVALUATION

Cost

Materials. The following items enter into the cost of using the SCRIBE system for worksheet response analysis.

1. SCRIBE sheets (1 per 360 worksheet responses).
2. Scoring mask (1 per 360 different items).
3. IBM output cards (6 cards per SCRIBE sheet used plus cards used in further analyses).

Processing. Some costs are for the preparation and processing of the data.

1. Data processing machine and operator time for sorting, listing and item analysis.
2. Data recording time on SCRIBE sheets (approximately 1 minute per 60 responses including ID information).
3. SCRIBE system time (100 sheets processed per minute).

Data Recording Time

Data from forty-five (45) worksheets for the UICSM programed instruction booklet, Part 104, were recorded on SCRIBE sheets. These worksheets contain 246 responses each. Two hours and thirty-four minutes were required. This is an average of about 72 responses perminute. Data from seventy (70) Part 104 worksheets were also recorded on SCRIBE sheets. Part 104 requires students to make only 225 worksheet responses. Recording these data required four hours and forty-five minutes time. This is an average of only

slightly more than 55 responses per minute[3] or about 5/7^{ths} the rate for Part 104. More sampling of parts is obviously required to obtain substantial information about the expected cost of recording data on SCRIBE sheets. However, one could probably be safe in estimating that recording will require about 1 minute per 60 items when student error rates are reasonably low as they were in Parts 104 and 104. Further investigation will be needed to determine the efficiency of this method for programs with higher or lower overall error rates.

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3 The lower rate is probably due to a more adverse item-to-ID information ratio. In the future it would be desirable to record the time for the ID information so that this could be determined.

SECOND STUDY

Use of "Condensed Tabulation Sheets" in Recording and Analyzing Worksheet Performance

A simple manual method was also tried. It resulted in a display like that shown in Figure 2.1, which is called a "condensed tabulation sheet," (C.T.S.). Advantages of this manual method are that it can be implemented immediately, without special preparations or equipment, and that it makes a large amount of data available for inspecition in a single compact display. Branches and other special features of programs are readily accommodated in the display in visually effective ways. Disadvantages are that rows cannot be readily interchanged in order to make patterns in the data more obvious to the eye, and that row and column counts, available mechanically when the data is on cards, must be obtained manually.

The display, part of which is shown in Fig. 2.1, is for UICSM-PIP. Part 104. It was made in about four hours, plus two additional hours for planning and laying out the somewhat complicated column headings. The display is laid out on a sheet of Dietzgen 20 x 20 per inch graph paper, using a Koh-i-Noor No. 0 pen for the numerals and layout lines, and a Koh-i-Noor No. 2 pen for the "wrong" and "omit" code marks. These pens and paper are available at any source of drafting supplies. A "slider" consisting of a narrow strip of graph paper marked off and labeled exactly like the column headings is used when entering the data and also for some kinds of readout. A straight edge and stylus is useful in making column counts.

A C.T.S. as large as 260 cases by 830 items has been satisfactorily made and used. The time required to make this large chart was about 40 hours.

WRONG: 8 π: COULD SKIP — DIDN'T
OMIT: • ⋆: COULD SKIP — DIDN'T AND WRONG
SKIP: ∧ ⁂: COULD SKIP AN ENTIRE BRANCH — DIDN'T AND OMITTED ONE

C.T.S.
P.I.P. PART 104

UPPER AND LOWER 27% OF
P.I.P. TESTS 101 + 102 - 103 + 104
RANKED BY SCORE

Figure 2.1 Sample of Condensed Tabulation Sheet

THIRD STUDY

Use of the IBM Keypunch as a Method of Recording Student Worksheet Performance

A third way of reducing students' worksheet data is to punch IBM cards directly from the raw data. The same layout and coding can be used as that described in Section 1 for SCRIBE output cards, and the resulting cards are then identical to the SCRIBE cards. The time required (estimated) to punch cards directly is somewhat greater than that required to transcribe the same data onto SCRIBE sheets and somewhat less than that required to prepare a condensed tabulation sheet. However, whenever the response error rate rises much above the low level usually found in data from programed materials, the relative efficiency of direct punching rises. For reducing item data from tests where 30-60% error rates are common, direct punching is far more efficient than either of the other two methods described in this report. However, error rates of this level are seldom found in self-instructional programs, and there were no data in the UICSM-PIP units that met this condition.

The Three Studies Compared

When an IBM keypunch is available, direct punching of cards is the most satisfactory method of reducing student worksheet data. When IBM equipment is not available, the condensed tabulation sheet method is indicated. It is the most efficient manual method for processing item data we have been able to find. (Compare, for instance, the method of Campbell and Caron, 1961).

The SCRIBE system can be recommended only when a keypunch is not available (but service for subsequent processing of SCRIBE-punched cards is), the volume of data is large and a time lag on the order of weeks is not objectionable since the data must be sent in, processed, and returned.

Bibliography

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Eigen, L. D. The implications for research methodology of some behavioral studies in programed instruction. Psychol. in the Schools, 1964, 1, (2), 140-147.

Educational Testing Service. SCRIBE and the 501. Princeton, New Jersey: Princeton, N. J., 1961.

APPENDIX A

Sample SCRIBE Sheet

PROGRAMED LEARNING

NAME: _____

SCHOOL: _____

Be sure each mark is black
and
completely fills the answer box.

1	46	91	136	181	226	271	316		
2	47	92	137	182	227	272	317		
3	48	93	138	183	228	273	318		
4	49	94	139	184	229	274	319		
5	50	95	140	185	230	275	320		
6	51	96	141	186	231	276	321		
7	52	97	142	187	232	277	322		
8	53	98	143	188	233	278	323		
9	54	99	144	189	234	279	324		
10	55	100	145	190	235	280	325		
11	56	101	146	191	236	281	326		
12	57	102	147	192	237	282	327		
13	58	103	148	193	238	283	328		
14	59	104	149	194	239	284	329		
15	60	105	150	195	240	285	330		
16	61	106	151	196	241	286	331		
17	62	107	152	197	242	287	332		
18	63	108	153	198	243	288	333		
19	64	109	154	199	244	289	334		
20	65	110	155	200	245	290	335		
21	66	111	156	201	246	291	336		
22	67	112	157	202	247	292	337		
23	68	113	158	203	248	293	338		
24	69	114	159	204	249	294	339		
25	70	115	160	205	250	295	340		
26	71	116	161	206	251	296	341		
27	72	117	162	207	252	297	342		
28	73	118	163	208	253	298	343		
29	74	119	164	209	254	299	344		
30	75	120	165	210	255	300	345		
31	76	121	166	211	256	301	346		
32	77	122	167	212	257	302	347		
33	78	123	168	213	258	303	348		
34	79	124	169	214	259	304	349		
35	80	125	170	215	260	305	350		
36	81	126	171	216	261	306	351		
37	82	127	172	217	262	307	352		
38	83	128	173	218	263	308	353		
39	84	129	174	219	264	309	354		
40	85	130	175	220	265	310	355		
41	86	131	176	221	266	311	356		
42	87	132	177	222	267	312	357		
43	88	133	178	223	268	313	358		
44	89	134	179	224	269	314	359		
45	90	135	180	225	270	315	360		

B13PIX

APPENDIX B

Instructions for Recording Worksheet Data on SCRIBE Sheets

SCRIBE sheets are a lot like IBM answer sheets, but have the advantage of containing more information per page. They are designed so that the information on them can be automatically punched into IBM cards by a device called SCRIBE. Your job is to record the proper error and omission data from the student worksheets on the SCRIBE sheets. Each sheet must also contain certain identification information. The data which you are recording will be used to improve existing UICSM programed Instruction Project math materials and to study the effects of certain variables on performance within the program and on a later test.

Begin by obtaining a supply of SCRIBE sheets, a pencil, the worksheets to be recorded, and an error list mask designed for the worksheet for the part which you are recording. Be certain to note that underlined parts, e.g., 104 are not the same as non-underlined parts, e.g., 104.

Place the error list mask over the SCRIBE sheet. Line up the horizontal lines on the mask with those on the SCRIBE sheet.

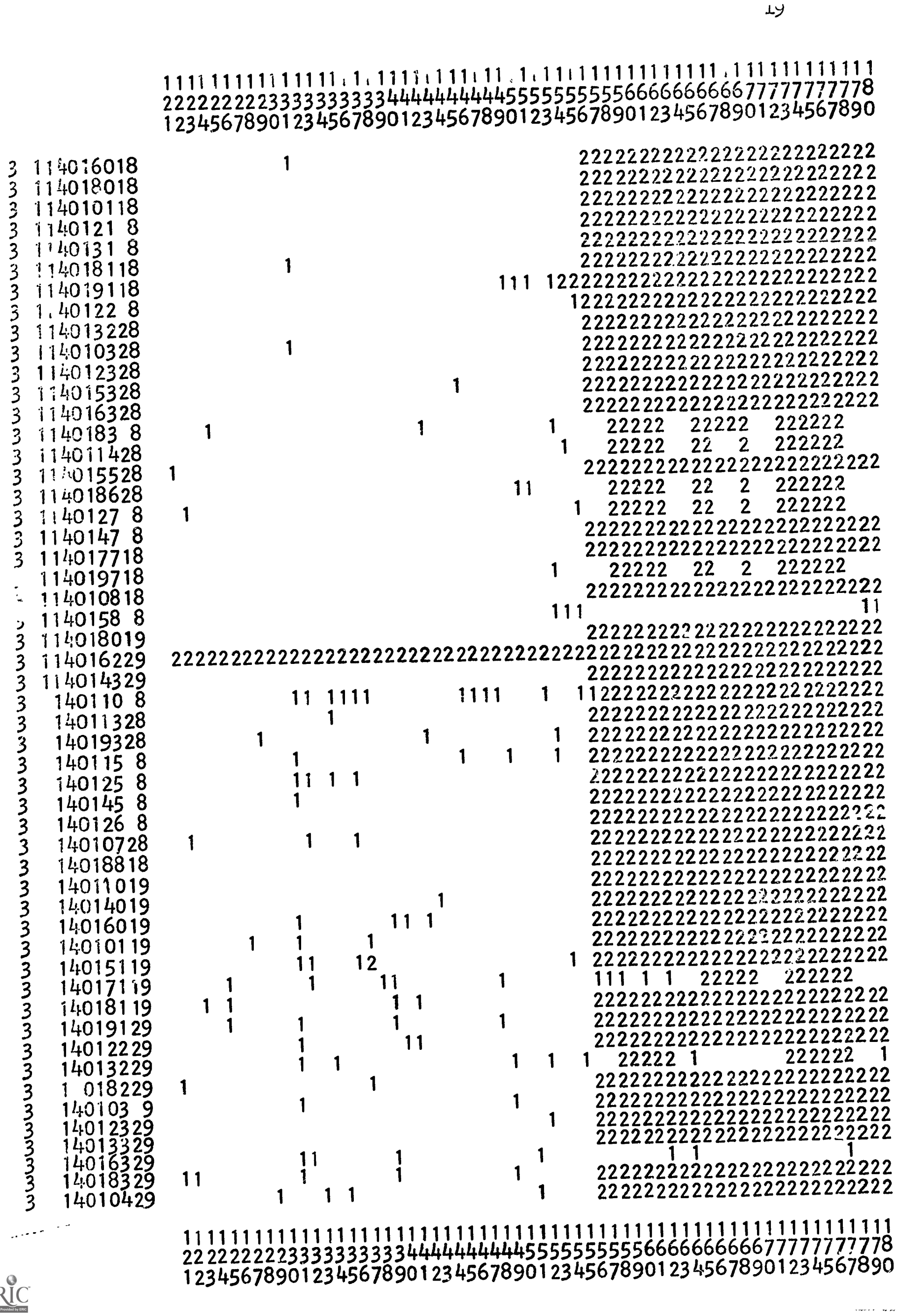
The ID information is to be recorded first. Determine the student's sex by looking at the name on the worksheet. Blacken in the rectangle labeled "1" in the second row of squares in the upper left-hand corner of the SCRIBE sheet if the student is a male. Blacken the number two rectangle if the student is a female. If you can't tell from the name, leave this part blank on the SCRIBE sheet. Next, fill in the squares corresponding to the student's school number and ID number. You will find this information on the worksheet in the space labeled "ID No."

The first digit of this number is the school number, the second two are the student's ID number. Now fill in the spaces indicated by the arrows leading from the words "fill in" on the error list mask. These identify the part number of the worksheet. See if there is a "U" following the ID number on the worksheet. If there is, fill in the indicated space on the SCRIBE sheet. If there is no "U," leave this space blank.

You are now ready to record the errors and the omits. Look through the worksheet until you come to the first error or omit. Note the page number and the problem number or letter of the problem done wrong or omitted. Find this page number on the mask and locate the problem number next to it or below it. Fill in the rectangle labeled "R" if the problem was wrong. If the problem was omitted, fill in the rectangle labeled "W." Some of the parts use "branching" programs, so you will find that some students will skip over whole sections of problems. When you have finished recording all the omits and all errors, look over the SCRIBE sheet to be sure that you have made all your marks black and that you have completed the ID information in the upper left portion of the sheet.

APPENDIX C

Sample Graphic Display of SCRIBE Output



APPENDIX D

Sample Item Analysis Output

Sample No. 018 Card No. 003 Sample Size 010

Item	Right	Wrong	Omit	W+O
001	010	000	000	000
002	010	000	000	000
003	010	000	000	000
004	010	000	000	000
005	010	000	000	000
006	010	000	000	000
007	010	000	000	000
008	010	000	000	000
009	010	000	000	000
010	008	001	001	002
011	009	001	000	001
012	010	000	000	000
013	010	000	000	000
014	009	000	001	001
015	010	000	000	000
016	009	001	000	001
017	010	000	000	000
018	010	000	000	000
019	009	001	000	001
020	008	000	002	002
021	008	000	002	002
022	008	000	002	002
023	010	000	000	000
024	009	001	000	001
025	009	001	000	001
026	009	000	001	001
027	009	000	001	001
028	009	000	001	001
029	009	000	001	001
030	008	002	000	002
031	010	000	000	000
032	010	000	000	000
033	010	000	000	000
034	010	000	000	000
035	010	000	000	000
036	009	000	001	001
037	009	000	001	001
038	010	000	000	000
039	010	000	000	000
040	010	000	000	000
041	010	000	000	000
042	008	002	000	002
043	010	000	000	000
044	009	001	000	00.
045	010	000	000	000
046	010	000	000	000
047	010	000	000	000
048	009	001	000	001
049	010	000	000	000
050	010	000	000	000
051	010	000	000	000
052	008	002	000	002
053	009	001	000	001

001	010	000	000	000
002	010	000	000	000
003	010	000	000	000
004	010	000	000	000
005	010	000	000	000
006	010	000	000	000
007	010	000	000	000
008	010	000	000	000
009	010	000	000	000
010	008	001	001	002
011	009	001	000	001
012	010	000	000	000
013	010	000	000	000
014	009	000	001	001
015	010	000	000	000
016	009	001	000	001
017	010	000	000	000
018	010	000	000	000
019	009	001	000	001
020	008	000	002	002
021	008	000	002	002
022	008	000	002	002
023	010	000	000	000
024	009	001	000	001
025	009	001	000	001
026	009	000	001	001
027	009	000	001	001
028	009	000	001	001
029	009	000	001	001
030	008	002	000	002
031	010	000	000	000
032	010	000	000	000
033	010	000	000	000
034	010	000	000	000
035	010	000	000	000
036	009	000	001	001
037	009	000	001	001
038	010	000	000	000
039	010	000	000	000
040	010	000	000	000
041	010	000	000	000
042	008	002	000	002
043	010	000	000	000
044	009	001	000	001
045	010	000	000	000
046	010	000	000	000
047	010	000	000	000
048	009	001	000	001
049	010	000	000	000
050	010	000	000	000
051	010	000	000	000
052	008	002	000	002
053	009	001	000	001
054	010	000	000	000
055	010	000	000	000
056	009	001	000	001
057	010	000	000	000
058	010	000	000	000
059	010	000	000	000
060	009	001	000	001