DOCUMENT RESUME

ED 229 419 TM 830 318

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TITLE Story Problem Formats: Some Interview Results.
SPONS AGENCY National Science Foundation, Washington, D.C.
PUB DATE Apr 83
GRANT SED-81-08134
NOTE 17p.; Paper presented at the Annual Meeting of the American Educational Research Association (67th, Montreal, Quebec, April 11-15, 1983).
PUB TYPE Speeches/Conference Papers (150) -- Reports - Research/Technical (143)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Cognitive Processes; Intermediate Grades; *Interviews; Junior High Schools; Learning Disabilities; Mathematical Models; Mathematics Education; *Mathematics Skills; *Memory; *Pictorial Stimuli; *Problem Solving; *Verbal Stimuli
IDENTIFIERS *Story Problems (Mathematics)

ABSTRACT

An interview protocol was devised to determine whether demands on working memory are reduced by the use of drawn or telegraphic formats. Students were chosen because some aspect of their group testing on presentation formats was provocative (e.g. high spatial score, but low reading comprehension score; high drawn score and low verbal score, etc.). Nineteen non-learning disabled (LD) students from grades 4-5 and 21 non-LD students from grades 6-8 were chosen. In addition, 11 LD students from grades 4-5 and 20 LD students from grades 6-8 participated. Two different protocols, with five separate procedures each, one for grades 4-5 and another for grades 6-8 were devised. Each procedure was structured to reveal a different aspect of the children's problem solving processes. The reported results are for the non-LD grade 4-5 students. Results imply: (1) that the pictures alone give a strong sense of the structure of the problem, and (2) that even after reading and thinking about problems the student generally cannot recall all the important information once the problem has been removed from view (i.e., students tend to focus on the data at the expense of the problem. (PN)

Story Problem Formats: Some Interview Results

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This research is part of an ongoing project to examine the effect on performance of three different presentation formats (verbal, drawn, and telegraphic) for mathematical "story" problems in grades 3-7. In this part of the project, individual interviews were conducted to explore possible explanations for experimental results derived from group testing in the previous year.

Background

Traditionally, most story problems in grades 3-7 have been presented in a verbal format. By limiting story problems to verbal presentations, however, variables important to problem solving are possibly being overlooked.

Drawings and diagrams have been shown to enhance performance on mathematics tests and prose comprehensions. Most research has been done using diagrams or drawings as adjuncts to a verbal form, however. It is also provocative to note that a commonly advocated problem solving strategy is to draw a picture. A possible reason that this practice is suggested is the assumption that making a sketch forces an understanding

[1]This research is a portion of an investigation by a National Science Foundation Grant (No. SED81-08134) awarded to the authors. Any opinions, conclusions, or recommendations expressed here are those of the authors and do not necessarily reflect the views of the National Science Foundation.

of the problem and that "hidden" relationships become apparent in the drawing. Since adjunct drawings prove to be so effective, then inital presentations in drawn formats may result in more solutions by learners.

Few words are used in the drawn format. Thus the drawn format involves at least two differences from the verbal format: reduced verbiage and the introduction of a drawing. This brings to mind a third format: the reduced verbiage or telegraphic format. Some text book series have presented a substantial portion of their story problems in a reduced verbiage format. The authors of such textbook series presumably have attempted to reduce the reading difficulty of the problems in the hope that better performance would result. However, little research exists which explicitly investigates the influence of such a format on reading difficulty or problem solving performance.

Group testing in the previous year investigated the three different presentation formats discussed above: 1) verbal (problems presented in complete sentences); 2) telegraphic (problems presented in short phrases); 3) drawn (problems presented pictorially, accompanied by short phrases and a question written in telegraphic form). Also examined (but not discussed here) was the effect of selected trait variables on problem solving. Approximately 1200 students (1000 normal and 200 learning disabled) in grades 3-7 were tested using intact classes. Table 1 summarizes the results of the group testing. It gives the mean scores for problems in the three formats. (The maximum score for each entry is 12.) With one exception, the drawn format was

significantly superior (using univariate ANOVAs with repeated measures and Neuman-Keuls) at every grade level for both normal and LD students. (No differences were seen for grade 7 LD students, probably because of the small sample size.) The telegraphic format resulted in significantly better performance than the verbal only at grade 3 for the normal students, but the reverse occurred at grades 3 and 6 for the LD students.

Although the results of the group testing are striking, many questions remain. In particular, the question of why the drawn versions of the problems are easier for children to solve is not answered by these results. In addition, the result that the telegraphic format does not appear uniformly to facilitate work with story problems is surprising, and runs counter to what might be inferred from some current textbook presentations. Hence it was decided to pursue the reasons behind these results during individual interviews with many of the same students tested in the group interviews.

Theoretical Framework

Some authors (Hiebert, Carpenter, & Moser, 1982; Hunter, 1964; Posner, 1967; Simon and Kotovsky, 1963) have suggested that a stumbling block in problem solving is the difficulty of grasping several items of information actively at the same time. Case (1978), Pascual-Leone (1970), Simon (1976), and others have hypothesized that this difficulty stems from the existence of a central computing space (variously called M space, working memory, short term memory, or operational memory),

whose size would limit the number of items of information that a problem solver can process at one time. Simon has hypothesized that working memory holds the inputs and outputs of all information processes as well as the control information that determines which process will be executed next.

According to this theory, students would become better problem solvers if the demands on working memory could be reduced. Case has delineated three factors that contribute to the overload of working memory: (1) the number of items to which the problem solver must attend at any one point in time; (2) the salience of the stimuli to which the subject must attend; and (3) the familiarity of the items of information. It is common experience that pictorial stimuli are are generally more salient than written stimuli. In addition, it is possible that a picture could make the items of information appear more familiar by incorporating stimuli that call to mind situations from the child's past experience.

The task then was to devise an interview protocol which might help determine whether demands on working memory are reduced by the use of drawn or telegraphic formats.

Method

Subjects

Subjects were students in two midwestern cities who had been tested in a group setting the previous year. Students were chosen for interviews because some aspect of their group testing was provocative (e.g. high

spatial score, but low reading comprehension score; high drawn score and low verbal score, etc.). Nineteen non-LD students from grades 4-5 and 21 non-LD students from grades 6-8 were chosen. In addition, 11 LD students from grades 4-5 and 20 LD students from grade 6-8 participated.

Protocols

Interviews were designed in which students were asked to work problems similar to the ones given during the group testing. However, students were requested to "think aloud" as they worked on the problems. Two different protocols, one for grades 4-5 and another for grades 6-8 were devised. Each protocol included five separate procedures. Each procedure was structured to help reveal a different aspect of the children's problem solving processes.

1. In the format hints (FH) procedure the experimenter first presented a problem in one of the formats to the child. The child was asked to read the problem aloud and to solve it, thinking aloud. After the child finished, the child was successively asked to work the same problem in a second and third format. If the child had found a solution to the problem in the previous format, the experimenter asked, "Would you do this one the same way?" If the child had been unable to get a solution, the experimenter asked, "Is this one any easier?"

2. In the progressive drawings procedure (PD), the experimenter successively presented three versions of a problem in a "drawn" format for the child to solve. The first version was essentially the problem

in telegraphic format, but with one phrase written in each of two or three blank cartoon-like frames. The second version was like the first, but in the frames were drawn schematic diagrams representing the problem. The third version was the actual drawn version used in the group tests. The experimenter questioned the child before presenting each of the versions, as in the FH procedure.

3. In the Explain (E) procedure the experimenter presented the child with a problem in either the telegraphic or drawn formats. The child was asked to read the problem aloud and to make sure that he or she understood it thoroughly. Then the words were covered and the the experimenter asked the child to "explain" the problem. If the original problem was in the telegraphic format, the child was also asked to make a drawing of the problem. Finally, the child was asked to work the problem.

4. In the Make Up (MU) procedure the experimenter presented the child with a problem in the drawn format from which all wording had been removed. The child was then asked to write a problem that would "go with" the drawing. Finally, the child was asked to work the problem he or she had created.

5. In the Similar Problem (SP) procedure the experimenter asked the child if any of the problems from the previous procedures (which were lined up on the table, drawn versions showing, for the child to see) were like the problems he or she had just completed in the current procedure. If the child said "yes", the expermenter would ask which

one(s) and why? Finally, if the child had identified more than one problem as similar, the experimenter would ask which problem was most like the problems in the current procedure.

The first four procedures (FH, PD, E, and MU) were administered, in order, three times to each child, using 12 different problems. The third time through the procedures, each of the problems was a matched companion (see below) to one of the problems previously presented. Hence it was meaningful to administer the SP procedure after the FH, PD, E, and MU procedures during this third and final pass through the procedures.

The procedures included both one step and multistep problems. A variety of arithmetic operations on whole numbers, fractions, and decimals were involved, as appropriate for each grade. The matching of companion problems was based in part on mathematical structure. That is, the solution to companion problems involved number sentences with the same structure, e.g. $A(B + C) = X$. Matching was also based in part on similarity of numbers, i.e. every effort was made to keep corresponding numbers in the matched problems comparable (number of digits, number of regroupings required in computation, etc.).

Procedure

Each child was interviewed for one hour. The entire interview was audio taped. Problems were presented on half sheets, one at a time to the children. The children were asked to write each solution on the same page as the problem. Each interview was transcribed, and analysis

of the interviews was made through the transcriptions, the tapes, and the written results.

Results

The results reported here are for the non-LD grade 4-5 students. The results of the PD and FH procedures were not particularly informative, and are not included here.

Table 2 gives the results of the E procedure. It is striking that only 15% of the problems described during the course of this procedure were completely accurate. (An explanation was considered to be completely accurate if each necessary piece of information, including the question, was alluded to in the explanation. Exact quantities were not required.) Twenty-five per cent of the problems contained all the essential information, but were lacking the question. In 19% per cent of the problems the question was included only after considerable prompting by the experimenter, but 38% of the problems were left with either no questions or incorrect questions. By comparison there was a large preoccupation with data. A full 42% of the problems contained all the correct data (even though the students were told they did not have to remember the exact numbers involved). The solution percentages on these problems were low (the problems were deliberately chosen to be of the more involved, multistep variety). Only 35% of the problems presented were correctly solved without any prompting from the experimenter, and 50% of the problems were never correctly solved.

Table 3 gives the results of the MU procedure. Sixty-two

percent of the MU problems were workable as presented. Sixty-six per cent of the problems were presented in a verbal format (complete sentences); 26% were presented in a drawn format (by labeling the drawing); and 11% were presented in a telegraphic format (phrases). In 68% of the problems, the problem description was essentially the same as was originally written by the experimenters. Only 1 problem (2%) was considerably more difficult than the original. Finally, it is interesting to note that 69% of the problems whose solutions were attempted were solved correctly.

Table 4 gives the results of the SP procedure. Eighty-one percent of the time the matched companion was correctly chosen as one of the similar problems. Reasons related to the mathematical structure of the solution ("same operation" or "same problem" or "similar action") were cited 53% of the time. Reasons related to incidental items ("same question", "same numbers", "same units", "same answer", "same length") were cited 41% of the time.

Discussion

The most striking result of the interviews occurred in the MU procedure. Those results imply that the pictures alone give a strong sense of the structure of the problem. The results of the E procedure, on the other hand, imply that even after reading and thinking about problems the students generally cannot recall all the important information once the problem has been removed from view. They tend to focus on the data at the expense of the structure of the problem.

Finally, the results of the SP procedure imply that children can recall similar problems they have worked, and that this process is perhaps facilitated by the use of drawn representations of the problems.

The combination of these results has lead to the following tentative hypothesis. Perhaps the solution of story problems is a two step process. First the student must determine problem solving situations from the past which are relevant to the solution of the problem (recall that the results of the SP procedure implied that the drawn format might facilitate this process). Once having done this, appropriate problem solving schemes are chosen and made available to short term memory. These schemes need inputs however, in the form of data. Perhaps in the process of retrieving the data from the problem, some of the sense of what is needed (and why) can be lost due to working memory overload (recall that the E procedure implied this possibility). However if a drawn format is present during the entire process, the structure of the problem is kept in front of the student at all times, making it less likely for the problem solver to "forget" what he or she is about, and thus reducing the demands on working memory (recall that the MU procedure implied this).

It must be understood that these closing remarks are extremely tentative, and are made more in the spirit of speculation than scientific fact. They are based upon a very limited sampling of problems and children. Further, the interpretation and collection of the data has been painfully prone to experimenter bias.

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Table 1

Format Means from Group Testing

Grade	LD/Normal (N)	Drawn (D)	Verbal (V)	Telegraphic (T)	Neuman-Keuls*
3	Normal (159)	6.78	6.11	6.42	D>>V, D>T, T>V
	LD (56)	5.88	5.20	4.55	D>>T, D>V, V>T
4	Normal (173)	7.86	7.08	7.12	D>>V, T
	LD (51)	6.14	5.24	5.49	D>>V, D>T
5	Normal (163)	7.63	7.37	7.28	D>V, T
	LD (65)	6.31	5.51	5.72	D>>V, T
6	Normal (175)	6.43	6.15	5.94	D>>T, D>V
	LD (35)	5.46	4.94	4.23	D>>T, V>T
7	Normal (184)	6.42	5.97	5.97	D>>V, T
	LD (17)	4.53	3.88	4.41	

*>>: significant at 0.01 level; >: significant at 0.05 level

Table 2

Frequencies and Percents for Explain Procedure Categories

Category	Frequency	Percent
Problem Description		
Essential Information		
(0) none included	11	21
(1) some included/all after prompting	29	55
(2) all included	13	25
Question		
(0) not included/incorrect	20	38
(1) included after prompting	10	19
(2) included without prompting	23	43
Data		
(0) none included/completely incorrect	11	21
(1) some included	20	38
(2) all included	22	42
Overall Adequacy		
(0) totally inadequate	10	19
(1) incomplete	35	66
(2) completely accurate	8	15
Problem Solution		
Number of steps correct		
(0) none	14	28
(1) one	12	24
(2) both	24	48
Quality of Success		
(0) no solution	26	50
(1) solution after prompting	8	15
(2) solution without prompting	18	35

Table 3

Frequencies and Percents for Make Up Procedure Categories

Category	Frequency	Percent
Problem Quality		
Completeness of Information		
(0) incomplete	14	30
(1) includes redundent/extraneous data	2	43
(2) complete	31	66
Question		
(0) not included	12	26
(1) included after prompting	15	32
(2) included without prompting	20	43
Answer		
(0) given as part of the problem	6	13
(1) no answer possible	5	10
(2) not given as part of problem	36	77
Data		
(0) none included	3	6
(1) some included	7	15
(2) all included	37	78
Overall quality		
(0) not a solvable problem	14	30
(1) nothing to be solved	4	9
(2) solvable	29	62
Other Issues		
Solution (if attempted)		
(0) incorrect	5	16
(1) approximate solution given	5	16
(2) correct	22	69
Presentation format		
(D) drawn	11	23
(T) telegraphic	5	11
(V) verbal	31	66
Similarity to Experimenter problem		
(0) none	2	4
(1) some similarity	13	28
(2) essentialy same	32	68

Table 4

Frequencies and Percents for Similar Problem Categories

Category	Frequency	Percent
Companion Problem Chosen		
(0) not at all	12	18
(1) as one of many	15	23
(2) as the only one/best one	38	58
Reasons given for choice(s)		
Same operation	19	29
Same problem	8	12
Similar action	8	12
Same question	9	14
Same numbers	7	11
Same units (e.g. dollars)	8	12
Same answer	1	2
Same statement length	1	2
Other	4	6