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ABSTRACT

The study sought to determine the relationship between problem solving ability and problem presentation stimuli of textbook (T), student generated (S), pictorial (P), textbook and pictorial (TP), and student generated and pictorial (SP). Ten problems for each stimulus were presented to ninth grade algebra students randomly assigned within IQ groupings to the five stimulus presentation groups. IQ effects were significantly with treatment T superior to all the treatments except S for the low IQ group. Treatment TP was found to be significantly least effective. (JG)

The Effectiveness of Textbook, Student Generated, and Pictorial Versions of Presenting Mathematical Problems

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A relatively new area within the field of complex problem solving involves the subjects' mode of conceptualizing and representing a problem either verbally or visually. Frandsen and Holder (1969) suggested that when problems such as anagrams, syllogisms, and rate of travel are presented verbally, solving them requires "holding in mind" and manipulating the multiple components of the problems.

Evidence of the facilitative effect of pictorial presentations in learning appears inconclusive. Runquist and Hunt's (1961) results indicated that in a concept learning task, verbal presentation was superior to pictorial presentation. Koenke (1970) found that relevant pictures added little to the recall of descriptive paragraphs and that specific directions to attend to the pictures were not effective. Samuels (1970) also demonstrated that pictures interfere with the acquisition of reading responses, especially with poor readers.

Although Cronbach and Snow (1969) and Gagne and Gropper (1965) did not find evidence of spatial or verbal aptitude interactions with the learning of verbal or pictorially illustrated concepts, Sherrill (1970) demonstrated that in presentations of mathematical word problems, prose together with an accurate picture was superior to prose alone which, in turn, was superior to prose together with a distorted picture. The subjects' performance

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was significantly correlated with IQ, reading score, and grade average, which suggests that the results may not be ranked in the same order for groups of subjects with different aptitudes.

The verbal structure of mathematical problems is a neglected area of research. Kilpatrick (1960) found that word problem length was the best predictor of problem difficulty, and that variables such as vocabulary difficulty and sentence length were not useful predictors of problem difficulty. An alternative to the textbook statement of a problem could be a verbal statement in the language of the learner. Keil (1964) showed that subjects who wrote and solved their own problems performed better on an achievement test than subjects who solved textbook problems. It seems likely that the effectiveness of mode of presentation of verbal problems depends upon the aptitude of the student. In the present study, the relationship between aptitude and the effectiveness of textbook, student generated, pictorial, textbook and pictorial, and student generated and pictorial presentations was investigated.

METHOD

Subjects. The Ss were 116 ninth-grade algebra students from a New Jersey parochial high school. The 61 boys' and 55 girls' IQ ranged from 92 to 137, with a mean of 115.5.

Materials. Word problems were selected from algebra and pre-algebra textbooks to represent a variety of content and levels of difficulty. Pictorial versions of the problems were generated which minimized the verbal content, and were shown to three judges who confirmed the pictures' fidelity to the problems. In a

preliminary phase of the study, six algebra students were given the pictorial versions of the problems and were required first to solve the problems, then to write their own version of each problem. Thus, there were five versions of the ten problems: (1) The textbook version (T), (2) The student version (S), (3) The pictorial version (P), (4) The textbook version with the accompanying picture (TP), and (5) The student version with accompanying picture (SP). See Figure 1 for an example of the versions.

Insert Fig. 1 about here

Fifty overhead transparencies were prepared, one for each of the five versions of the ten problems. Answer booklets were constructed with eleven 8 x 10 pages; the top half of each page was labeled "NOTES" and the bottom half "SOLUTION".

Design. Each S was randomly assigned to one of the five treatment groups. In each group, the subjects solved the ten problems presented in one of the five versions (S, T, P, SP, TP).

Five measures of subject performance in solving the problems were obtained: (1) Correct answer, (2) Correct method; that is, the use of the correct arithmetic operation and procedure, (3) The percentage of total words and symbols copied during presentation, (4) The percentage of critical information copied during presentation; that is, the numbers and relations necessary to solve the problem and a statement of the question of the problem, and (5) The presence of a sketch in the notes or solution of the problems.

Procedure. The Ss came into the room in groups of six to ten. The experimenter read the directions telling the Ss that they would see a problem projected on the screen for one minute, and they could write down anything under the "NOTES" section of the answer sheet that they thought would help them solve the problem. They were not told to copy the problem. A sample problem was presented and at the end of one minute, the projector was turned off and the Ss were allowed three minutes to solve the problem on the "SOLUTION" section of the answer sheet. At the end of three minutes, the Ss were told to turn the page and the first problem was presented for one minute, followed by a three minute period for solution. Immediately after the 3 minutes, the second problem was presented. This procedure was continued until all 10 problems were presented.

RESULTS

An intercorrelation of the variables revealed significant correlations with IQ only for number correct ($r = .397$) and correct method ($r = .420$). There were four significant correlations between dependent variables: number correct and correct method ($r = .921$), percentage of words copied and percentage of critical information copied ($r = .722$), percentage of words copied and the presence of a sketch ($r = .319$), and correct method and percentage of words copied ($r = -.233$).

A 5×3 treatment by IQ (low--below 110, medium--110-119, high--above 119) analysis of variance was performed for each of the five dependent measures on the means of (1) the three easiest problems, (2) the three medium difficulty problems, (3) the four hardest problems, and (4) all ten problems. The difficulty of the problems was determined by rank according to the number of correct answers over all five treatments. For each analysis of variance in which there was a significant treatment by IQ interaction, a one-way ANOVA over the treatments was performed separately within each IQ group (Winer 1962, p. 244).

Number correct and correct method. There were significant IQ main effects for all problem difficulty levels on number correct and correct method. The only significant IQ-treatment interaction was for correct method on the easiest problems $F(8,101) = 2.32$, $p < .05$. The ANOVAS within IQ groups revealed significant treatment effects only for the low IQ group $F(4,101) = 14.58$, $p < .01$. Figure 2 shows the means for each IQ group for the five treatments. A Newman-Keuls test within the low IQ group showed that the treatment T was significantly

Insert Fig. 2 about here

($p < .05$) superior to all the treatments except treatment S. Also, treatment TP was significantly ($p < .05$) the least effective of all the treatments.

Percentage of words copied and critical information copied. At all problem difficulty levels, there were significant treatment effects but no significant IQ effects for the percentage of words copied. For the mean of all ten problems, a Newman-Keuls test showed that Ss in the P and the TP treatments copied a significantly ($p < .01$) greater percentage of words than Ss on the other treatments. There were no significant treatment or IQ effects at any problem difficulty levels for the percentage of critical information copied.

Presence of a sketch. There were significant ($p < .01$) treatment effects at all problem difficulty levels and a significant IQ effect for the most difficult problems. On the difficult problems, the medium and high IQ groups made significantly ($p < .05$) more sketches than the low IQ groups. There was a significant IQ-treatment interaction for the easiest problems $F(8,101) = 2.28$, $p < .05$. Newman-Keuls tests showed treatment P superior to the others in the medium and high IQ groups. Figure 3 shows the mean number of sketches for each IQ group on the five treatments.

Insert Fig. 3 about here

DISCUSSION

The finding that the Textbook and the Student versions were superior for low IQ Ss when the criterion was correct method suggests that pictures may have interfered with problem solving for these subjects. Although the Picture version was superior to the others when the criteria were the percentage of words copied and the presence of a sketch, this advantage did not appear to facilitate solving the problems, since the Picture version was not superior when the criterion was the number correct or correct method.

The two variables that measured the information copied during problem presentation revealed some interesting relationships. It appeared that obtaining the information necessary to solve a problem did not depend upon the total amount of information copied. In fact, the significant negative correlation between the percentage of words copied and correct method indicates that copying the entire problem during presentation may have interfered with solving the problem later. Perhaps the subjects who copied fewer words did so because they thought about what they were copying and attended only to the critical information that facilitated solving the problem later.

The findings of the present study did not support Sherrill's (1970) results that prose with a picture was superior to prose without a picture in presenting verbal problems. This may be partially explained by differences in the tasks and levels of problem difficulty. Further research is needed to determine the differences between the textbook and student versions that appear to make the former more effective than the latter for low IQ subjects. Also, additional research may reveal reasons for the finding that different modes of presentation were differentially effective for low IQ students but not for medium and high IQ students when correct method was the criterion, while the opposite was true when making a sketch was the criterion.

Some of the dependent measures used in the present study might be considered to be unobtrusive, and their use in research of this type should be encouraged. Multiple criterion measures could reveal relationships in the problem solving process that would not be apparent in the use of a single measure such as correct answer or response latency which are often used in problem solving studies.

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TEXTBOOK: What is the height of a flagpole if it casts a shadow 20 feet long when a 6-foot surveyor's pole casts a shadow 4 feet?

STUDENT: If a 6 foot pole casts a shadow 4 feet, how long would a pole have to be to cast a 20 foot shadow?

PICTORIAL:

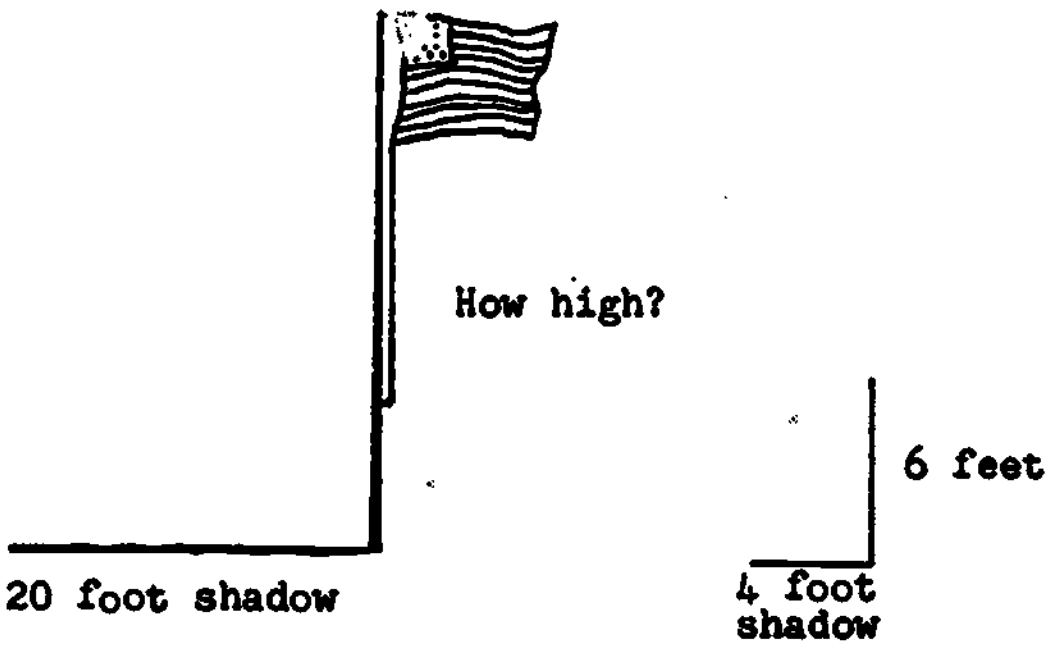

Figure 1. Textbook, student, and pictorial versions of a problem.

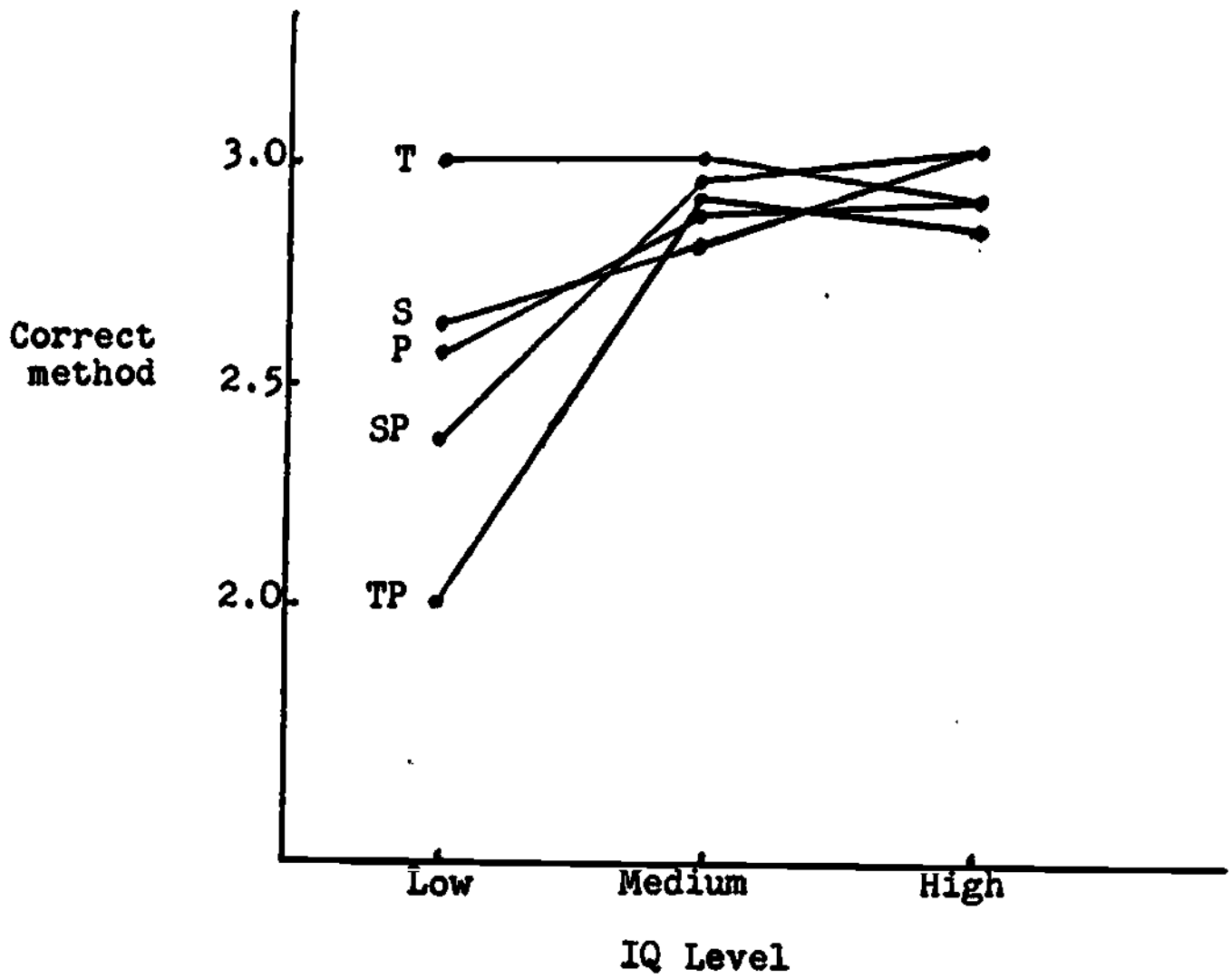

Figure 2. Mean Correct Method on the three easiest problems for each treatment and IQ group.

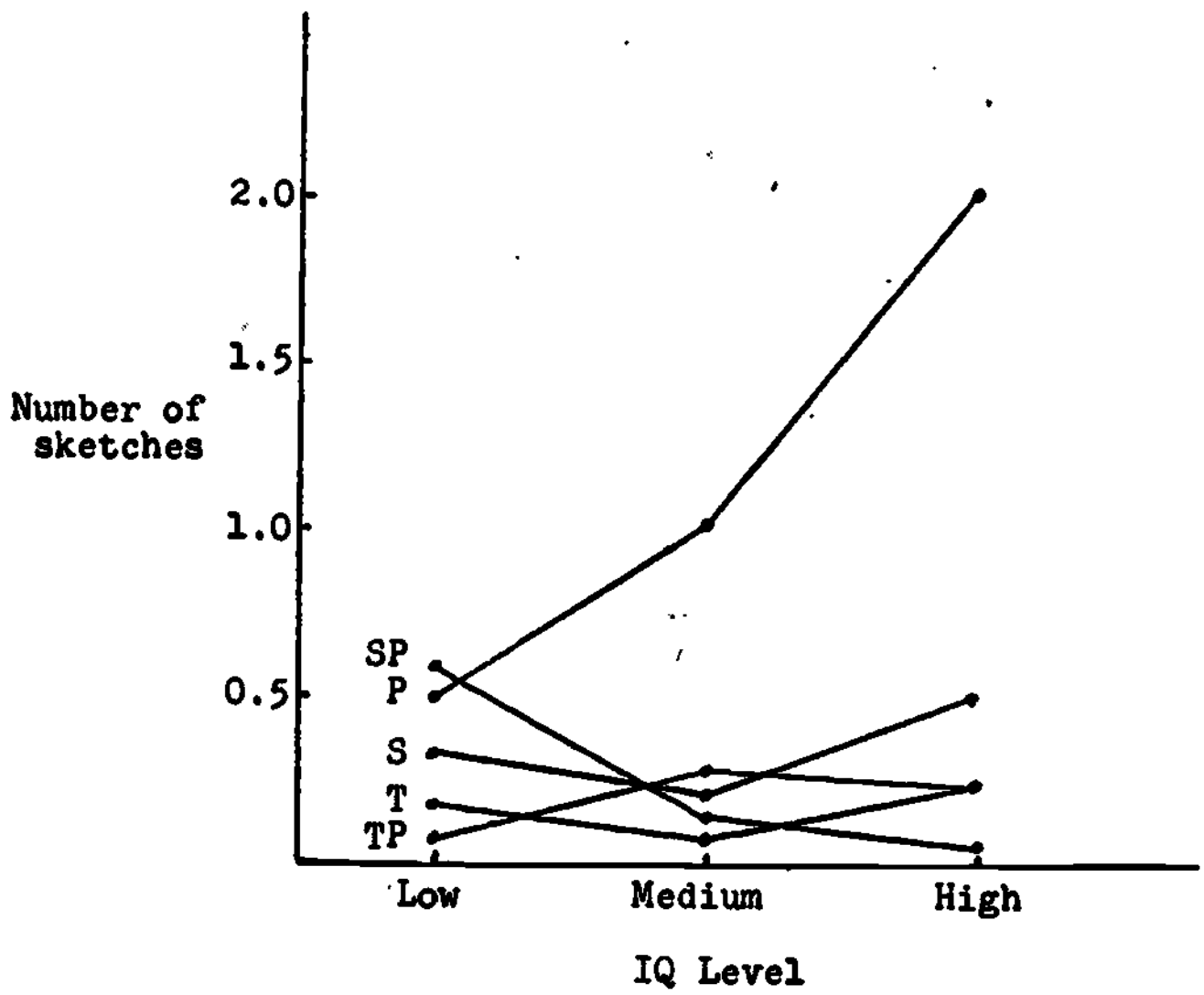

Figure 3. Mean Number of Sketches on the three easiest problems for each treatment and IQ group.