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ABSTRACT

In a series of five experiments, novices read a text on computer programming, and engaged in one of the following learning strategies: advance organizer, model elaboration, comparative elaboration, normal reading (control). Results of transfer tests indicated a pattern in which the treatment groups excelled on the ability to put the information together in a novel way (far transfer) but the control group excelled on retention of single pieces of information. In addition, results of recall tests indicated a pattern in which the treatment groups excelled on recalling conceptual idea units while the control group excelled on recalling technical details. These findings suggest that elaboration techniques can be applied to "real world" materials, and can result in more integrated, broader learning outcomes. (Author)

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Elaboration Techniques for Technical Text: An Experimental Test of the Learning Strategy Hypothesis

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Report No. 79-3

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Abstract

In a series of five experiments novices read a text on computer programming, and engaged in one of the following learning strategies: advance organizer, model elaboration, comparative elaboration, normal reading (control). Results of transfer tests indicated a pattern in which the treatment groups excelled on the ability to put the information together in a novel way (far transfer) but the control group excelled on retention of single pieces of information. In addition, results of recall tests indicated a pattern in which the treatment groups excelled on recalling conceptual idea units while the control group excelled on recalling technical details. These findings suggest that elaboration techniques can be applied to "real world" materials, and can results in more integrated, broader learning outcome.

When a student is given a new technical text to read, there are several mathemagenic activities (Rothkopf, 1970) that may be used to influence the learning of the material. For the purpose of the present paper mathemagenic activities are defined as (1) behaviors produced by the learner, (2) during the course of learning, (3) which influence the learning of the material. Other researchers have referred to these behaviors as manifestations of "learning strategies" (see O'Neil, 1978), or "generative activites" (see Wittrock, 1974). For example, the following specific types of mathemagenic activites have generated considerable research attention: answering adjunct questions, taking notes, writing summaries after portions of the material, and producing associative elaborations. While research results have been far from consistent, there does appear to be an emerging concensus that activities such as note taking (see Peper & Mayer, 1978), writing summaries (see Wittrock, 1974), answering adjunct questions (see Rothkopf, 1966, 1970), and even asking subjects to verbalize during learning (see Gagne & Smith, 1962; Weener, 1974) often influence the outcome of learning.

These researchers suggest an idea that could be called the "learning strategy hypothesis" -- mathemagenic activities aimed at making the learner actively integrate new information with existing knowledge affect the encoding, storage and eventual use of new material on performance tests. An important issue, to be discussed later in this introduction, concerns whether the effects of learning strategy affect mainly how much is encoded (quantity of learning) or how the information is encoded (quality of learning).

This paper attempts to provide information concerning the learning strategy hypothesis by focusing primarily on the role of elaboration techniques in learning new technical information. In general, past work in this area has followed one of two paradigms: associative elaboration techniques using artificial verbal materials or integrative and comparative elaboration techniques using real world materials.

There has been a great deal of research on the effects of associative elaboration. In general, the materials used are paired associates or lists of to-be-remembered stimuli; and the elaboration procedure involves making a visual and/or verbal association between the two stimuli. For example, if a paired associate item is DOG-BICYCLE, as associative elaboration would be to visualize a picture of a dog riding (or chasing) a bicycle or to use a sentence such as "the dog is riding the bicycle" (Bower, 1972). There has been relatively consistent support for the finding that associative elaboration increases retention performance as compared to control or simple repetition procedures (see Rowher, 1973, Jensen & Rowher, 1963; Lynch & Rowher, 1971; see Bower, 1972; see Levin, 1976).

More recently, there has been increasing interest in applying the elaboration technique to the learning of real world materials such as prose passages. In particular, Weinstein, (Note 3, 1978), Diekhoff (Note 1), and Dansereau (1978) have revised the elaboration techniques used in verbal learning studies for use in school curricula. The two most common types of elaboration used are comparative and integrative elaboration. Comparative elaboration occurs when a learner actively explains the relation between two concepts in the text; integrative elaboration occurs when the learner explains the relation between a concept in the text and some concepts already in the learner's memory. These techniques differ from associative elaboration mainly in degree; they require more than a single mnemonic sentence or image.

The shift of interest towards integrative and elaborative elaboration is important on both theoretical and pedagigic grounds. It allows for testing of theories of learning and memory in more demanding situations, and it allows for the development of techniques which may influence the design of school instruction (Glaser, 1978). Unfortunately, there has not been a rich body of research data using real world materials that is comparable to what is already known about elaboration in verbal learning tasks. This study attempts to provide more information in this area by using real world materials, namely a text on computer programming.

Two major problems face instructional psychologists regarding integrative and comparative elaboration techniques with real world materials. First, there is the empirical question of determining whether elaboration affects learning, and if so, under what conditions. Second, there is the theoretical problem of determining the cognitive processes and mechanisms which account for the findings.

This paper addresses the first issue by testing for elaboration effects in a variety of situations and using a variety of dependent measures. Based on previous research with advance organizers (Mayer, 1975a, 1976) there is some reason to suspect that elaboration will have its strongest effects on low ability learners and with technical text. Of particular interest in this regard is the suggestion that elaboration effects in paired associate learning situations may be particulariy strong for low ability learners (Gallimore, Lam & Speidel, 1977). Under these circumstances the learner may be less likely to automatically use an elaboration strategy, i.e. relate the new material to what he or she already knows. This study, therefore, will focus on learners who are not familiar or skilled with respect to the to-be-taught material.

Insert Table 1 About Here

This paper also attempts to provide some information on the second problem of theory. Table 1 provides a framework for discussion of theories of elaboration, by presenting several variables involved. First, the external (or directly observable) variables that lead to learning are the instructional materials and procedures, and the student's learning behavior. The external variables that result from learning are measures of test performance. The internal or cognitive varibles are the encoding process and the learning outcome.

Three basic theories regarding the effects of elaboration activities are a general motivation theory, an attention theory, and an assimilation theory. The general motivation theory states that learner activities such as elaboration increase the general level of interest in the learner and thus should result in more material being encoded, more information in the learning outcome, and an overall increase in test performance. Danseraeau (1978) refers to this function of elaboration as a "support strategy." The attention theory states that elaboration serves to draw the learner's attention to information that is emphasized in the questions, and thus should increase encoding and performance of only specific pieces of information. These two theories are summarized in the middle panels of Table 1.

The assimilation theory (Mayer 1975b, 1979) suggests that meaningful learning depends on the following conditions: the to-be-learned material must be received (reception), the learner must have a meaningful set of past experiences that could be used as an assimilative context (availability), and the learner must actively use an assimilative context during learning (activation). Elaboration techniques may have some effects on the third process -- activation. If this process occurs, then the outcome of learning should be a broader, more integrated structure since new information is incorporated into a broader set of past experiences. This broader outcome should result in a pattern of superior transfer performance, especially on problems requiring putting information together in a novel way. These predictions are outlined in the bottom of Table 1. The present experiments explored the predictions of these theories.

In the present series of experiments, students who had no prior experience or expertise with computers, read a manual explaining a computer programming language. Four treatment groups were used: the advance organizer group was given a concrete model prior to reading for use in reading the text, the model elaboration group was given a sheet (after each page in the text) which asked the reader to write down how the new material related to a concrete model of the computer, the comparative elaboration group was given a sheet (after each page in the text) which asked the reader to write down how the just learned statement was similar to and different from some other statement, and the control group received only the text. It can be noted that model elaboration group and to some extent, the advance organizer group were encouraged to relate new information to existing knowedge (i.e. integrative elaboration) while the comparative elaboration group was encouraged to related pieces of the new information with one another (i.e. comparative elaboration). To test the nature the resultant learning outcomes subjects were asked to solve a series of transfer problems ranging from retention to far transfer; in other studies, subjects were asked to recall sections of the text and protocols were scored with respect to the amounts of conceptual and technical information recalled.

Experiments 1 and 2

Experiment 1 investigated the effect of placing an advance organizer (in this case, a familiar model of the computer) before the text. Experiment 2 investigated the effect of asking subjects to answer questions after each page that required relating the text to the familiar model of the computer. Because Experiments 1 and 2 used equivalent subjects populations and procedures they are described together below.

Method

Subjects and design. Experiment 1 and 2 each involved 40 different subjects from the University of California, Santa Barbara. The subjects had no previous experience with computers or computer programming. In Experiment 1, 20 subjects served in the advance organizer group and 20 subjects served in the control group. In Experiment 2, 20 subjects served in the model elaboration group and 20 subjects served in the control group. All subjects took the same posttest so comparisons by type of questions are within subject comparisons.

Materials. A 10-page typewritten booklet for all subjects (Text Booklet) was constructed that explained nine commands from a simple file management language. The language was similar to that described by Gould & Ascher (Note 2) and consisted fo the following commands: FROM, FOR, AND FOR, OR FOR, COUNT, TOTAL, LET, Super LET, LIST. Some typical programs are shown in Table 2. One text page was devoted to each command, and contained the following information: the format of the command, when the command could occur in a program, an example of the command, a description of the actions that would be executed for the example.

In addition, a 3 page advance organizer (Model Booklet) was constructed for the advance organizer group. The booklet provided familiar, concrete examples of records (such as library catalogue cards), of programs (such as a list of things to do), and of the components of the computer. The long-term storage function of the computer was described as a file cabinet, the sorting function was described in terms of an in-basket, save basket and discard basket on an office desk, the computational functions were described in terms of an eraseable memory scoreboard, and the output function was described as a note pad. A 2 x 3 foot board was constructed which contained all the featurs of the computer: a small 4-drawer file cabinet, three sorting baskets, an eraseable scoreboard with labeled spaces, and a note pad.

In addition, nine sheets (one for each command) were constructed to be added to the Text Booklet for the model elaboration group. Each sheet asked the subject to explain in writing how a certain command related to a concrete office situation involving a worker, file cabinet, sorting baskets, memory scoreborad and note pad. For example, the sheet for the FOR COMMAND said: "Consider the following situation. An office clerk has an in-basket, a save basket, a discard basket, and a sorting area on the desk; the in-basket is full of records; each one can be examined individually in the sorting area of the desk and then be placed in either the save or discard basket. Describe the FOR command in terms of what operations the clerk would preform using the in-basket, discard basket and sorting area." Thus each sheet asked the subject to elaborate on the information in text by expressing it in concrete, familiar terms.

The text materials, for all subjects, consisted of a deck of 20 3 x 5 inch index cards with one question typed on each card. Half the questions presented a program and asked the subjects to interpret what it accomplished (Interpretation Type) while the other half presented a question that could be answered by writing a program (Generation Type). For each type there were five problem lengths: single sorting with no computations and no counting (Sorting 1), multiple sorting with no computations and no counting (Sorting 2), sorting and counting (Counting), sorting, counting and computation (Computing 1), sorting, counting and complex computation (Computing 2). Questions involved car registration records or student records at a university, and were different from examples given in the text. Examples are given in Table 2.

Additional materials included a blank answer sheet, a subject pretest that asked about the subject's past experience with programming, and a stopwatch.

Insert Table 2 About Here

<u>Procedure</u>. Subjects were run in small groups of approximately three per session. Subjects were randomly assigned to treatment except that all subjects in a session received the same treatment, and average SAT-Mathematics scores were equated for all groups. First, subjects were seated in individual desk chairs, and asked to complete the subject

pretest. The instructions were read and subjects were given their booklets. Subjects in the advance organizer group were given the Model Booklet and the concrete model was placed on a table in front of them; after reading, the booklet and model were removed and the Text Booklet was given. Subjects in the control group for Experiment 1, read the Text Booklet first; then it was removed, and concrete models were given along with a brief verbal description. Subjects in the model elaboration group were given only the Text Booklet with the nine elaboration sheets added, one after each command. Subjects in the control group for Experiment 2 read only the Text booklet. Subjects were told to read at their own rates, not to memorize, and to be prepared for a test. Only model elaboration subjects were allowed to write during reading.

When a subject finished reading, the subject was moved to a booth in a nearby room and given a pile of test cards and an answer sheet. Subjects were told to answer one question at a time, using an answer sheet, and not to go back to work on any previous cards. The cards alternated between five interpretation and five generation question, and within each set of five the questions were orderd from shortest to longest. The advance organizer group and its control group were also given a sample "record" card prior to the test which showed the type of information on the file for each card and for each student; in addition, the concrete model was in view during the test. These manipulations were intended to serve as a mild retrieval aid during problem solving. The model elaboration group and its control took the same test but were not given the sample record or concrete model.

Result

Three subjects, out of the 80 used in the two experiments, indicated they had past experience with computers or computer programming so their data were replaced by data from new subjects run in their places. The test responses were scored without knowing which treatment the subject had received. Each of the 20 answers were scored as correct or incorrect using a linient criterion. For generations items, all the commands had to be given in the correct order although format errors were allowed; in addition, the Computing 1 and 2 answers were counted as correct if all commands were given except the final LIST. For interpretation items, the subject had to correctly tell whether the output would be a list of names, a total, an average or a ratio and had to correctly describe the question being answered by the output.

An analysis of variance was performed on the data for Experiment 1, with treatment as the between subjects factor and type and length of test item as the within subjects factors. There was an overall effect in which the advance organizer group performed better than the control group, 60% versus 41% correct respectively, $F(1,36) = 7.71$, $p < .01$. However, the main focus of this experiment was to investigate any differences in the pattern of performance for the two groups. The analysis revealed a marginally reliable interaction between treatment and problem length, $F(4,144) = 2.27$, $p < .07$. This interaction may be summarized by saying that the control group excelled on short problems involving simple sorting while the advance organizer group excelled in long problem requiring use of all statements to make a ratio. The proportion correct response for the two groups by length of problem is given in the top portion of Table 2. These results are consistent with previous findings using a less English-like programming language, in which an advance organizer aided performance particular on problems requiring far transfer (Mayer, 1975a, 1976).

A major new question addressed in the present paper is whether elaboration techniques affect learning and learning outcomes in a manner similar to advance organizers. The data for Experiment 2 were analyzed in the same way as for Experiment 1. The model laboration group performed better overall than its control group, 60% versus 47% correct respectively, but the difference was only marginally reliable, $F(1,36) = 3.80$, $p < .01$. However, as in Experiment 1, the main focus was to investigate the differences in pattern of performance for the two treatment groups. As in Experiment 1 there was a significant interaction between treatment and problem length, $F(4,144) = 6.44$, $p < .001$. Also as in Experiment 1, the interaction can be described by saying that the control group excelled on near transfer problems involving sorting while the model elaboration group excelled on longer problems that required putting all the learned commands together in a novel way. The proportion correct response for the two treatments by length of problem is given in the bottom portion of Table 3.

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Insert Table 3 about here

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In order to more closely compare the effects of model given as an advance organizer (as in Experiment 1) and the model as an elaboration device (as in Experiment 2), the data for Experiments 1 and 2 were analyzed together. It must be pointed out that the two experiments were conducted separately. An analysis of variance was performed using the between subject factors of learning treatment (advance organizer plus model elaboration groups versus control-1 and control-1), and experiment (advance organizer plus control-1 versus model elaboration plus control-2), and the same within subject factors as above. The analysis revealed an overall effect due to treatment, 59% versus 44% correct respectively, $F(1,72) = 11.36$, $p < .005$. This difference reflects the overall differences obtained separately in Experiments 1 and 2. In addition, there was a significant interaction between treatment and length of problem, $F(4,288) = 6.31$, $p < .001$, that reflects the two separate patterns obtained in Experiments 1 and 2. Although the overall performance was equivalent in Experiments 1 and 2 (50% versus 53% correct respectively), there was some evidence that the treatment x problem length interaction obtained in the two experiments was not identical. The analysis revealed a significant interaction among treatment, problem length and experiment, $F(4,288) = 2.45$, $p = .05$. Since the control groups were not identical in the two experiments it is difficult to make a strong case concerning the relative effects of the advance organizer and the model elaboration treatments. However, the three way interaction suggests that the treatments, while increasing transfer performance in both treatments, may not be identical. This problem is analysed more fully in Experiment 4.

Experiment 3

Experiment 3 was conducted in order to determine whether a different type of elaboration technique--making comparisons about information within text--had the same effect as model elaboration. In short, the goal of Experiment 3 was to determine whether elaboration activity *per se* can influence the breadth of learning, or whether only presenting a concrete familiar model increases the breadth of learning. It should also be noted that the subjects used in Experiment 3 were high school juniors rather than college students.

Method

Subjects and design. The subjects were 26 high school juniors who were participating in a summer program at the University of California, Santa Barbara. Thirteen subjects served in the comparison elaboration group and 13 served in the control group. Three subjects in each group has some minor experience with computers and 10 subjects in each group had no experience at all.

Materials. The same Text Booklet and test materials were used as in Experiments 1 and 2. In addition, eight comparison elaboration pages were constructed to be inserted after each of the last eight pages in the booklet. Each elaboration page contained two questions such as: "How is FROM like FOR?" And "How is FROM different than FOR?" Thus, for the comparison elaboration group, after each of the last eight pages of text there was a question page with a question on top asking how two commands were alike and a question half way down the page asking how they were different. The questions always pertained to the commands on the preceding page and some other previously presented command.

Procedure. The procedure was the same as in Experiment 2 except that the elaboration group was given the new type of elaboration booklet. The procedure for the control group was identical to Experiment 2.

Results

The responses were scored and analyzed as in Experiments 1 and 2. The analysis was conducted on only the 20 subjects who had no prior programming experience, and a summary of the results is given in Table 4.

The comparison elaboration group averaged 74% correct compared to 52% correct for the control group, $F(1,18 = 8.94, p < .01$. As in the previous experiments, the main focus was on whether there were differences in the pattern of transfer performance for the two groups. The treatment x length interaction obtained in the previous experiments was not as pronounced in the present study, but there was a reliable interaction among treatment, problem length and problem type, $F(4,72) = 4.05, p < .01$. Apparently, the treatment x length interaction was obtained only for the interpretation problems--elaboration subjects performed much better on longer problems while control subjects excelled on short ones--while the elaboration subjects performed better on all lengths for the generation problems. Individual t-tests revealed that the elaboration group outperformed (at the .05 level) the control group mainly on three of the generate problems (sort-1, sort-2, and compute-1) and on two of the interpret problems (count and compute-2). These problems seem to be those of intermediate difficulty, with the two groups both performing quite well on the easiest problems (sort-1 and sort-2 of the interpret problems). The pattern of performance for the six experienced subjects was quite different: there was no evidence for any difference in the pattern of performance for the two groups and performance reached an overall 93% correct for both groups.

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Insert Table 4 about here

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Although the manipulations used in Experiments 1, 2 and 3 appear to have influenced the breadth of transfer performance, it is not possible to make comparisons across experiments. Experiment 4 was conducted as a replicatory test of these experiments, and as a means for directly comparing the three treatments used in previous studies--advance organizer without elaboration, model elaboration without an advance organizer, and elaboration without a model. In addition, Experiment 4 investigated the idea, suggested in previous experiments (Mayer, 1977) that meaningful instructional techniques might have their strongest effects on low ability subjects, who presumably lack appropriate encoding strategies on their own.

Method

Subjects and design. The subjects were 80 students recruited from the Psychology Subject Pool at the University of California, Santa Barbara. None had any programming experience. Each subject served in one cell of a 4 x 2 factorial design. The first factor was method of instruction: advance organizer, model elaboration, comparison elaboration, control. The second factor was mathematical ability: above or below 520 on Mathematics SAT. All subjects took a 20 item posttest so comparisons by type of question are within subject comparisons.

Materials. The same 10-page text and 20-item posttest was used in this study as in the three previous studies. In addition materials included the same 3-page advance organizer from Experiment 1, the 9 pages of model elaboration questions used in Experiment 2, and the 8 pages of comparison elaboration used in Experiment 3. Two 2 x 3 foot posters were constructed which gave a list of all the statements (and the format of each), and a list of the information given on each record in a file.

Procedure. The procedure was the same as in Experiments 1, 2 and 3 for each respective treatment group except that instructions for the test were modified. Subjects took the test in nearby room that had both posters on the wall, and were told that they could refer to the posters when answering the test questions. The procedure for the control group was the same as in Experiment 2.

Results

The test results were scored as in Experiments 1, 2 and 3. Table 5 shows the proportion correct response on each of the 10 kinds of questions for each of the four treatment groups, partitioned into low and high ability. An analysis of variance was performed using the factors of treatment, ability, test type and test length. There was no significant overall effect due to treatment, but there was a overall effect in which high ability subjects performed better overall than low ability subjects, $F(1,72) = 16.55$, $p < .001$.

The main focus of this study was on whether the treatment groups produced different patterns of performance by type of posttest problem. The interaction between treatment and problem length appears in the same general direction as in earlier studies but failed to reach statistical significance. However, there was a marginally reliable interaction between ability and treatment, $F(3,72) = 2.37$, $p < .08$, which suggests that it might be fruitful to analyze the performance of the high and low ability subjects separately.

The main finding of the analysis performed on the data for low ability subjects was a significant interaction between treatment and problem length, $F(12, 144) = 1.99$, $p < .05$, similar to that obtained in previous studies. However, there was no overall or interactive effect due to treatment for the high ability subjects. These findings were consistent with the idea that high ability subjects come to the experiment with existing strategies and cognitive structures for understanding mathematical concepts while low ability subjects are more likely to lack such strategies and knowledge--thus instructional techniques that evoke assimilative encoding strategies are most likely to influence low ability learners.

In order to determine differences among the groups on individual problems in Table 5, Newman-Kuels Tests were performed with a .05 level of significance. For high ability subjects there were no differences among the groups on any of the 10 problems except for two minor points--the comparison elaboration group performed better than all others on generate compute-2, and the model elaboration group performed worse than all others on generate sort-2. However, for low ability subjects there are interesting differences among the groups for problems requiring increasing amounts of creative problem solving. There were no differences on interpret sort-1, interpret sort-2, interpret count and generate sort-1 problem. On interpret compute-2, and on generate compute-2, the most conceptual problems, the advance organizer group performed better than all other groups. On the generate compute-1 problem, requiring moderate conceptual performance, the model elaborate group becomes indistinguishable from the advance organizer group and both groups perform better than the others. Finally, on generate sort-2 and count problems, the comparison elaboration group joins the advance organizer and model groups, in that all three are superior to the control group.

Thus the three treatments seem to vary with respect to how broad a transfer ability they foster: the advance organizer group excells on all transfer problems as compared to the control group, the model elaboration group excells on all but the most conceptual problems as compared to the control group, and the comparison elaboration group excells on only some of the mildly conceptual problems as compared to the control group.

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Insert Table 5 about here

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Experiment 5

The results of Experiments 1, 2, 3 and 4 suggest that elaborative activities such as model elaboration and comparative elaboration result in superior performance on some types of transfer problems. Experiment 5 replicates Experiment 4 except that the test consists of asking subject to recall portions of the text. The foregoing results suggest that elaboration treatments should result in increased recall, especially of information needed for writing novel programs.

Method

Subjects and design. The subjects were 48 college students who had no prior experience with computers or computer programming, and who reported scores below 600 in Mathematics SAT. Twelve subjects served in each of four treatment groups -- control, advance organizer, model elaboration, comparative elaboration. Since all subjects took the same test, comparisons by type of test category are within subject comparisons.

Materials. The instructional materials were identical to those used in Experiment 4. The test consisted of three sheets of paper which asked the subject to recall all that he or she could remember about FOR, COUNT and Super LET statements, respectively.

Procedure. The procedure for the instructional phase of the study was identical to Experiment 4, except that only subjects who reported scored below 600 in Mathematics SAT were allowed. For the test phase, subjects were moved to a nearby room, and were given the FOR test sheet. Subjects were told to take all the time they needed and to write down all they could remember in an organized way. After the subjects wrote their recall protocols for FOR, that sheet was collected, and a test sheet for recall of COUNT was given; then that sheet was collected, and the Super LET test was given.

Results

Scoring. In order to score the three recall tests, the corresponding sections of the Text Booklet were parsed into idea units. Each idea unit consisted of a sentence or clause, and expressed one major idea. There were 36 idea units for the FOR statement, 19 for the COUNT statement, and 24 for the Super LET statement. Four major types of idea units were noted:

Extra text idea units. These occurred in general introductions to each section of the text, and one unit could be related to each statement. An example for the FOR statement is: "There are four sorting statements: FROM, FOR, AND FOUR, OR FOUR." This information was presented earlier in the booklet and served as a table of contents, (N = 3).

Format idea units. These occurred in the first paragraph of the text, and provided a general definition of the statement and a description of the format for the statement. For example, "The format of the command is FOR _____ IS CALLED _____." "All letters must be capitalized." (N = 30).

Order idea units. These occurred in just one line between the first and second paragraphs, and provided information concerning the placement of a statement in a program with other statements. For example, "This command can only be used in a program if previous COUNT and TOTAL commands have been used," (N = 6).

Procedure idea units. These occurred in the second paragraph of the text, and provided a description of the processes which took place when the command was executed. For example, "The computer would find its retained records." "The number is placed next to the AVERAGE label," (N = 40).

The recall protocol for each subject was broken down into idea units. For each idea unit, an attempt to classify it as one of the 79 units units from the text. If the unit clearly was not one of these it was counted as either a reference to the model (model intrusion), a novel inference (inference), a connecting sentence that added no information (connective), a vague summary of some of the information from the text (vague summary), or a general summary of a problem that could be solved using the information in the text (general summary). Since less than 10% of the units from the protocols fell into these categories and there was no pattern across groups, they were not used in the final analysis. Thus for each subject the data were summarized across all three tests into the following: the number of extra idea units recalled, the number of format units recalled, the number of order units recalled and the number of procedure units recalled. In addition, these numbers were divided by 3, 30, 6 and 40, respectively, to proportion correct for extra, for format, for order, and for procedure idea units.

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Insert Table 6 About Here

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Analysis. The first quetion addressed in this analysis is whether there were any differences among the groups in overall amount recalled. The left portion of Table 6 given the average number of idea units recalled (and proportion correct) on each of the four types of categories for each of the four treatment groups. As can be seen, there appear to be differences among the groups with respect to overall amount recalled -- an average of 15.0 idea units for the control group, 14.4 for the advance organizer group, 19.2 for the model elaboration group and 23.5 for the comparative elaboration group. An analysis of variance was performed on the recall data (i.e. number correct) with the four treatments as the between subject factor and the four types or recall categories as the within subject factor. The analysis revealed that the overall differences in average number of units recalled among the groups was significant, $F(3,44) = 3.40$, $p < .05$. In addition, a second analysis of variance was performed as above but using percent recalled as the dependent measure, thus providing a more uniform weighing to the four recall categories. As in the above analysis, the four groups differed significantly with respect to overall percent recalled, $F(3,44) = 4.32$, $p < .01$. Thus, these results may be summarized by stating that there were overall or quantitative differences in the amount recalled by the groups with the elaboration groups recalling more than the other groups.

The second question raised in the present analysis concerns whether the learning outcomes of the treatment groups differed in terms of structure or quality, as well as differing in quantity. Since the advance organizer and model elaboration subjects excelled on far transfer in the previous studies, they are expected to emphasize idea units in their recall protocols that would support far transfer. The two types of idea units that might best support far transfer are procedure units -- since they describe operations that occur inside the computer -- and order idea units -- since they describe how one command relates to others in a long program. These predictions apply, but to lesser extent, to the comparative elatoration groups since it showed moderate transfer ability in previous studies. Finally, the control subjects should emphasize idea units that support near but not far transfer, since these subjects excelled only on near transfer in previous studies. The two types of idea units that best fit this discription are extra idea units --which simply tell where a command was discussed in the text -- and format idea units -- which describe how a single command is formated.

These predictions would be consistent with a pattern of interaction in which the experimental groups outperform the control group on order and procedure categories but not on format and extra categories. As can be seen in the left side of the Table 6, this pattern was generally obtained -- especially for the advance organizer and model elaboration groups. An analysis of variance performed on the number recalled data revealed a significant treatment x type of category interaction, $F(9,132) = 2.04$, $p < .05$. Similarly the anlaysis performed on percent correct data also revealed a significant interaction, $F(9,132) = 2.78$, $p < .01$.

The center panel of Table 6 allows for a clearer summary of the differences in emphasis among the four groups. As can be seen the advance organizer and model elaboration groups recall less of the factual information (extra and format) and more conceptual information (procedure and order) as compared to the control group, while the comparative elaboration group shows only a hint of this pattern. An analysis of variance based on the four treatments as the between subjects factor and the two categories as the within subject factor, revealed that this interaction was significant, $F(3,44) = 3.19$, $p < .05$.

In addition, a "conceptual index" was computed for each subject by comparing the number of idea units recalled that would be helpful for transfer (i.e. order and procedure units) to the total number of idea units recalled. This measure was constructed in order to give a measure of the emphasis or structure of the recall protocol that is independent of overall quantity recall. Further, the index provides for a more detailed analyses of differences between the three experimental groups. The index was computed for each subject based on the formula:

$$\frac{P + O}{E + F + P + O} = \text{concept index}$$

where P is the number of procedure units recalled, O is the number of order idea units recalled, E is the number of extra idea units, and F is the number of format idea units recalled. As is shown in the right side of Table 6, the four treatment groups differed with respect to the emphasis of their protocols, and an analysis of variance revealed that the differences are significant, $F(3,44) = 4.89$, $p < .01$. Individual t-tests comparing each pair of treatment groups revealed that the model elaboration and advance organizer groups each scored significantly higher (at $p < .05$) on the index that the control group with $t(22) = 2.12$ and $t(22) = 2.15$, respectively. In addition, the comparative elaboration group scored marginally higher than the control group, at $t(22) = 1.90$, $p < .10$; but marginally lower than the model elaboration group, at $t(22) = 1.57$, $p < .10$. Thus the model elaboration and advance organizer group showed the highest emphasis on conceptual material, followed by the comparative elaboration group, with the control group lowest of all.

Conclusion

These results provide consistent evidence that elaboration techniques can influence the outcome of learnin^, even when the to-be-learned material is in instructional text. Thus, there is positive support for the "learning strategy hypothesis" - the idea that how the learner encodes the material influences what is learned. In the present experiments, elaboration techniques consistently produced a pattern of superior performance on applying learned knowledge to novel problems (or recalling conceptual information) but not on performance of simple problems (or factual recall). In addtion, it should be noted that these results were obtained mainly for low ability subjects and using unfamiliar technical materials.

These results provide some information that may be useful in developing a theory of mathemagenic activities. These results are most consistent with the assimilation theory summarized in the introduction. While the specifics of the cognitive processes underlying meaningful learning are still unclear, this work does allow a general hypothesis. First, learner activities such as elaboration encourage two important internal cognitive processes: students search for relevant past experiences (availability of the learning set) and students actively relate this existing knowledge to key concepts presented during learning (activiation of a learning set). When these conditions are met, then the encoding process is one of assimilating and integrating new information. When these conditions are not met, such as with some control subjects, new information must be added to memory piece by piece without integration. The assimilative encoding process results in a broader congitive structure, which supports transfer to creative problem situations.

In addition, these results suggest some interesting differences among the effects of the three instructional treatments (advance organizer, model elaboration, comparative elaboration). There is some evidence that these treatments may have influenced the following processes in different ways: selection of information to be encoded, availabiliy of an assimilative context, activation of an assimilative context. For example, the advance organizer provided a rich assimilative context (availability) that learners were likely to use during reading (some activation) and which encouraged emphasis on selecting conceptual information that fit in with the context (selection). The model elaboration treatment provided some assimilative context as part of the question (some availabiltity) and then strongly encouraged learners to actively connect new information to the context (availability) and to foucs on coneptual information in doing so (selection). This resulted in slightly poorer transfer than the advance organizer group, perhaps due to more emphasis on the material in the questions. Finally, the comparative elaboration treatment did not explicitly provide an assimilative context although subjects may have generated one in order to answer the questions (low availability); this treatment encouraged learners to focus on key features including non-conceptual ones (some selection) and to compare them (some activation). This resulted in somewhat poorer transfer perhaps due to less integration and more recall overall perhaps due to the practice reqired by the questions. All groups, however, showed a pattern of behavior suggesting a broader outcome than that acquired by the control group. The fact that these results were strongest for low ability subjects suggests that the need to ensure integration encoding processes via instructional manipulation is strongest for learners who would not normally use these strategies for meaningful learning.

Further work is required to test the generality of these findings using different subject matter. In addition, further work is required to pinpoint the specific effects of different types of elaboration procedures (such as comparative versus model). It is hoped that additional research in this area will bridge the gap between elaboration studies using paired associates and elaboration training programs for use in schools, (e.g., Dansereau, 1978; Weinstein, 1978).

Footnote

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Table 1
Three Theories of Elaboration

Instruction	Learning Strategy	Encoding	Learning Outcome	Performance
What and how is information presented?	What activities are engaged in?	How much and how is information encoded?	How much is acquired and how is the cognitive structure organized?	How much and what kind of material is recalled or applied in transfer?
Motivation Theory				
Text passage	Elaboration	Much encoded	More information outcome	More recall & transfer
	Control	Less encoded	Less information outcome	Less recall & transfer
Attention Theory				
Text passage	Elaboration	Focus on information	More relevant information in outcome	More recall & transfer for relevant information
	Control	No focus	Less relevant information in outcome	Less recall & transfer for relevant information
Assimilation Theory				
Text passage	Elaboration	Integrate relevant information with existing knowledge	Broader, more conceptual outcome	Superior transfer and recall of conceptual information
	Control	No integration	Narrower outcome	Superior specific retention of non-conceptual information

Table 2

Examples of Test Problems for a Simple File Management Language

Sort 1

List the owners' names for all cars weighirg 3000 pounds or more.

FROM AUTOMOBILE
FOR WEIGHT IS CALLED 3000 OR MORE
LIST NAME

Sort 2

List the owners' names for all late model green Fords.

FROM AUTOMOBILE
FOR YEAR IS CALLED 1976 OR
MORE AND FOR COLOR IS CALLED
GREEN AND FOR MAKE IS CALLED
FORD
LIST NAME

Count

How many cars are registered in Santa Barbara County?

FROM AUTOMOBILE
FOR HOME COUNTY IS CALLED
SANTA BARBARA
COUNT
LIST COUNT

Compute 1

What is the average current value of all cars?

FROM AUTOMOBILE
COUNT
TOTAL CURRENT VALUE
LET TOTAL + COUNT BE CALLED AVERAGE
LIST AVERAGE

Compute 2

What percentage of 1977 cars are Chevrolets?

FROM AUTOMOBILE
FOR YEAR IS CALLED 1977
COUNT
LET THIS BE CALLED COUNT 1
AND FOR MAKE IS CALLED CHEVROLET
COUNT
LET THIS BE CALLED COUNT 2
LET COUNT 2 + COUNT 1 BE CALLED AVERAGE
LIST AVERAGE

Table 3

Proportion Correct Response by Length of Problem

For Four Instructional Groups--Experiment 1 and 2

Instructional Group	Length of Test Problem: Sort-1	Sort-2	Count	Compute-1	Compute-2
Experiment 1					
Advance Organizer	.66	.66	.63	.58	.45
Control (Post Organizer)	.63	.44	.43	.33	.22
Experiment 2					
Elaboration	.65	.58	.64	.64	.45
Control	.66	.64	.41	.38	.27

Note.--For experiment 1: Group x Length interaction, $p < .07$; Group, $p < .01$

For Experiment 2: Group x Length interaction, $p < .05$; Group, $p < .01$

For Experiment 1 and 2 Combined: Group x Length interaction, $p < .001$; Group, $p < .005$

Table 4

Proportion Correct Response by Type and Length of

Problem for Two Instructional Groups--Experiment 3

Instructional Group	Type and Length of Test Problem									
	Generate					Interpret				
	Sort 1	Sort 2	Count	Compute 1	Compute 2	Sort 1	Sort 2	Count	Compute 1	Compute 2
Elaboration	.80	.80	.60	.70	.40	.90	.90	1.00	.75	.55
Control	.35	.45	.65	.30	.15	.90	.90	.65	.65	.25

ote -- Group x Type x Length Interaction, $p < .01$; Group, $p < .01$

Table 5

Proportion Correct Response by Type and Length of

Problem for Two Instructional Groups--Experiment 4

Instructional Group	Generate: Sort-1	Generate: Sort-2	Generate: Count	Generate: Compute-1	Generate: Compute-2	Interpret: Sort-1	Interpret: Sort-2	Interpret: Count	Interpret: Compute-1	Interpret: Compute-2
Low Ability										
Advance Organizer	[illegible]	.50	.65	.55	.55	.75	.80	.90	.75	.65
Model Elaboration	.65	.55	.55	.45	.10	.65	.75	.90	.60	.40
Comparison Elaboration	.65	.50	.65	.20	.20	.70	.75	.95	.35	.25
Control	.50	.25	.25	.05	.00	.75	.75	.80	.65	.40
High Ability										
Advance Organizer	.65	.75	.45	.55	.50	.85	.90	.85	.85	.55
Model Elaboration	.55	.45	.65	.50	.35	1.00	.90	.90	.85	.75
Comparison Elaboration	.70	.75	.70	.75	.70	1.00	.95	.95	.85	.65
Control	.85	.75	.55	.50	.45	1.00	1.00	.95	.85	.75

Note.-- For Low Ability Subjects: Treatment x Length Interact, $p < .05$. For High Ability Subjects: Treatment x Length Interaction, n.s. For each kind of problem, all scores in dark are equivalent, all scores in white are equivalent, and differences between light and dark are significant.

Table 6

Average number of recalled idea units (and proportion recalled) by type of idea unit for four treatment groups - Experiment 5.

Treatment Group	Type of Idea Unit: Extra	Format	Order	Procedure	Type of Idea Unit: Extra & Format	Order & Procedure	Conceptual Index
Advance Organizer	1.0(.33)	3.7(.12)	.8(.14)	8.7(.23)	4.7	9.7	.63
Model Elaboration	.4(.18)	4.9(.16)	2.3(.37)	11.7(.30)	5.3	13.9	.73
Comparative Elaboration	1.1(.37)	8.3(.28)	2.5(.42)	11.6(.29)	9.4	14.1	.61
Control	1.2(.40)	6.3(.21)	.9(.15)	6.6(.16)	7.5	7.5	.45

Note. -- Numbers in parenteses indicate proportion recalled. Conceptual index is based on number of order and procedure units recalled divided by total number recalled for each subject.

For number of idea units recalled: Overall effect of Group, $p < .05$;

Group x Type interaction, $p < .05$.

For Conceptual Index: Overall differences, $p < .05$.

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