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ABSTRACT

The effect of a meaningful instructional context and practice variety on rule retention was investigated. One hundred high school students participated. The design was a 2 by 3 completely randomized factorial design. The instructional context factor had two fixed levels: context and rule. The practice variety factor had three fixed levels: broad-, narrow-, and no-practice. Students learned computer programming rules either from a context or a rule booklet on Day 1 of the experiment. Students in the broad and narrow practice groups received either a broad or a narrow practice booklet consisting of ten practice instances with feedback on Day 2. All students took a posttest 11 days after initial learning. An analysis of variance on retention scores found both the broad and narrow practice groups scoring significantly higher ($p < .01$) than the no-practice groups. No significant main effect for instructional context was found. It was concluded that practice instances facilitates rule retention. (Author/SD)

Effect of a Meaningful Context and Practice Variety on Rule Retention

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Running head: Rule Retention

Abstract

This study investigated whether a meaningful instructional context and practice variety would increase rule retention by activating a broad assimilative learning set. One hundred high school students (61 female and 39 male) participated, and the design was a 2X3 completely randomized factorial design. The instructional context factor had two fixed levels: context, rule. The practice variety factor had three fixed levels: broad-, narrow-, and no-practice. Students learned computer programming rules from either a context or rule booklet on day one of the experiment. Students in the broad and narrow practice groups received either a broad or narrow practice booklet consisting of 10 practice instances with feedback on day two, and all students took a posttest 11 days after initial learning. An analysis of variance on retention scores found the broad practice and narrow practice groups scoring significantly higher ($p < .01$) than the no practice groups. No significant main effect of instructional context was found. This study concluded that inquisitory practice instances during initial learning facilitates rule retention.

Effect of a Meaningful Context and

Practice Variety on Rule Retention

Two research reviews (Davis, 1966; Sterrett & Davis, 1954) reported that 50-80% of the initial amount of classroom learning is forgotten over time. One type of learning outcome that makes up much of school learning is rules (Gagné, 1970; Merrill & Boutwell, 1973). Layton (1932) reported that the mean rule retention test score after twelve months was only one-third of the mean test score at the end of an algebra course. The present study investigated the effects of two instructional events on rule retention.

Meaningful learning occurs when preexisting knowledge in memory is activated by and integrated with new learning material (Ausubel, 1968; Mayer, 1975b). Ausubel describes learning material as being potentially meaningful if the component elements of the material are easily encoded into a network of related and stable ideas in memory. Much evidence indicates the superior retention of meaningful learning over rote learning of information (Ausubel, 1968). Studies investigating the effect of instructional context on the learning and retention of rules have not demonstrated the effectiveness of a meaningful context (Hannum, 1973; Mayer, 1975a, 1976). These studies represent a variety of operational definitions of meaningful context. In teaching subjects computer programming rules, Mayer (1975a, 1976) defined a meaningful context by including either a(n): (a) expository computer program example, (b) flowchart with program statements, (c) diagram model of a computer expressed in familiar terms, or (d) concrete, manipulable model of the computer, before the rule text which referred back to the particular meaningful context. None of the four methods facilitated the learning of programming skills. The concrete and diagram model groups excelled on interpretation and transfer test items, whereas groups not receiving a model excelled on writing programs similar to those in the text. In teaching subjects three electricity rules, Hannum (1973) operationally defined a meaningful context by relating examples in the text to a familiar practical application of each rule. The meaningful context condition in that study did not facilitate rule retention.

For rule learning to occur, Gagné (1977) explains that the component concepts of a new rule be accessible in memory, and therefore, he suggests stimulating the recall of component concepts of the rule immediately followed by a presentation of the rule statement. However, if the component concepts of the rule are not available in memory, it may be necessary for the instructional materials to present a set of propositions that link the component concepts of the rule to ideas that are available in memory, thus providing a meaningful context for the new rule.

It was proposed in this study that meaningful instructional material for rule learning would contain labels of domain and range concepts (Scandura, 1972) accessible in memory. If, however, concept labels in the rule statement are not accessible in the learner's memory, then the instructional material must provide a set of propositions that relate the new rule to the learner's cognitive structure. The instructional design technique used in this experiment to operationalize the meaningful context condition was to: (a) list the concepts in the rule statements that may be new and unfamiliar to the students; (b) for each concept determine the set of familiar concepts that will be used to introduce and link the new concepts; (c) prepare an introductory passage that relates the new terms in the rule statement to the familiar concepts and place the passage immediately preceding the rule instruction; and (d) immediately preceding a rule statement that includes any of the new terms, place a set of propositions that stimulate the recall of the new terms as they were related to the familiar concepts in the introductory passage.

If cognitive structure is a network of interrelated ideas (Ausubel, 1968), then the broader and more stable the learning set is during initial learning, the more likely the learner will locate and retrieve the necessary information about the rule so as to effect correct rule governed behavior. An instructional event that may broaden the assimilative learning set is to provide a variety of practice instances. An implication of the information processing theory of learning (Atkinson & Shriffrin, 1968; Shriffrin & Atkinson, 1969) is that practice instances should facilitate rule retention by enabling the learner to rehearse information about the rule in short-term memory, thus allowing the long-term memory storage and retrieval processes to occur. Klein (1975) found that practice instances during initial learning are effective for rule retention, whereas Gibson (1969) found that a variety of practice instances immediately after initial learning to a criterion is not effective for rule retention. It may be that the assimilative learning set is established during initial learning and that variation in practice instances may only be an important variable for rule retention if placed during initial learning. The instructional design technique used in this experiment to operationalize the broad and narrow practice conditions was to: (a) list the content-relevant concepts comprising the rule statements; (b) for each concept, list the irrelevant dimensions; (c) determine the scope of the irrelevant dimensions; and (d) generate rule instances which varied broadly or narrowly along the scope of the irrelevant dimensions of the concepts that comprise the rule statements.

The purpose of this study was to investigate whether two instructional events during initial learning would increase rule accessibility by activating a broad assimilative learning set. More specifically, this study investigated the following questions:

1. Does a meaningful instructional context or a variety of practice instances enhance rule retention?

2. Does variation in the scope of rule instances during practice have different effects on rule retention under different conditions of instructional context?

Method

Subjects and Experimental Design

Participants in this experiment were 154 students in six different math classes at Leon High School in Tallahassee, Florida. One of six experimental treatments was randomly assigned to each student. Fiftyfour students were later eliminated from the study. Of these, six students indicated previous experience with the experimental learning task on a preexperimental questionnaire and the remaining 48 students were absent either for the second experimental session or for the retention test. One hundred students completed participation in the experiment. Sixty-one were female and 39 were male.

The experimental design was a completely randomized factorial design. The first factor (instructional context) had two fixed levels which were context and rule. The second factor (practice variety) had three fixed levels which were broad practice (BP), narrow practice (NP), and no practice (OP). The six experimental treatment groups are represented in Figure 1.

Insert Figure 1 about here

Instructional Materials

A simplified version of the BASIC computer programming language was taught to the students. The objective of the instruction was to have students write a simple computer program representing the computer solution to a given problem statement. All instruction was presented in printed booklets. A total of four instructional booklets were developed with two booklets (context and rule) representing the instructional context variable, and two booklets (broad practice and narrow practice) representing the practice variety variable. The context and rule booklets presented the same rule statement and example for each of seven program coding rules (INPUT, OUTPUT, arithmetic, data transfer, GOTO, IF, END) and for each of four program syntax rules (arithmetic and relational expressions, program format, execution sequence). For every rule a rule statement was presented first followed by an expository instance of the rule with a written explanation of how the instance represents an application of that rule.

The rule booklet presented a brief introduction stating the instructional objective of the learning material and informing the students that they were to be tested over the material one week later. Next was a presentation of the 11 programming rules and expository instances. At the end of the booklet a problem statement was presented with a listing of a complete computer program representing a computer solution to the problem statement.

The context booklet included the same instruction as the rule booklet except for the following two additions.

1. A context section was placed between the introduction and presentation of the first rule. This instruction covered the topics of: (a) computer definition and characteristics, (b) five operational parts of a computer, and (c) computer program concept. The information presented in this section related terms in the rule statements to concepts with which the students would be familiar. Some of the rule statement terms were: data, program, statement, address label, memory unit, input, input card, store, output, arithmetic and relational operations, data transfer, execute, and execution sequence.

2. Immediately preceding a rule statement that included any of the above terms, there was a set of propositions that stimulated the recall of those terms as they were related to the familiar concepts.

The narrow practice booklet contained ten problems requiring the students in the narrow practice groups to write programs. The booklet was formatted with one or two problem statements printed on the front side of a page with space below each problem for the student's response. On the back of a page there was a correct program listing with feedback information indicating the correct application of the rules learned in the rule or context booklet. All ten problem statements required a linear or branched, nonlooping program and the problems were all similar.

The broad practice booklet contained ten problems different from those in the narrow practice booklet. The problems in the narrow practice booklet were of narrow scope, whereas the broad practice problems varied broadly from each other along the following dimensions: (a) the type and amount of input/output data and arithmetic/relational operations, (b) the type of operation elements, and (c) the type and length of the program. The booklet format described above for the narrow practice booklet was the same for the broad practice booklet. Also, each problem of the broad practice booklet required a linear or branched, nonlooping program.

Measures

A test booklet measuring the dependent variable of rule retention consisted of 10 problems requiring the students to write a linear or branched, nonlooping program. Two problem statements were placed on a page with blank space below a problem for the student's answer. No feedback was provided in the test booklet. A retention test score was calculated for each student indicating the total number of rules mastered on the retention test. A rule was mastered when the total number of appropriate rule applications minus the total number of inappropriate rule applications was at least 85% of the total number of times the rule had to be applied for the 10 problems. An appropriate application of a rule was defined as a correct application of the rule to the appropriate stimulus situation. An inappropriate application of a rule was defined as a correct or incorrect application of the rule to an inappropriate stimulus situation. Each test problem required none, one, or more than one application of each rule. For example, the INPUT rule had to be applied a total of 22 times on the retention test. For a student to demonstrate mastery of this rule, the total number of appropriate applications minus the number of inappropriate applications had to be at least 19. The retention test required the application of nine of the 11 rules taught in the instructional booklets, and therefore the possible range of scores on the retention test was 0-9.

A preexperimental questionnaire asking about the student's previous experience with computer programming, and an Algebra test consisting of six algebra problems were developed. The Algebra test was used to determine the equality of treatment groups. The total correct score calculated for each student on the Algebra test was the sum of correct item responses on the test. Each item was scored as either correct or incorrect, and the possible range of test scores was 0-6.

Instructional time was another dependent variable measured. Instructional time was defined as the total number of minutes each student took to finish the instructional booklet(s) received in the experimental sessions. The instructional time for the four practice groups that received two booklets was the sum of time spent on both booklets.

Experimental Procedure

The experiment was conducted during regular class periods on three successive school days. During the first two days (Thursday and Friday) the students received the instructional booklets. The students then commenced a one week vacation, and received the test booklet on the Monday of their return. The retention interval was the number of days between the first and third sessions (11 days).

During session one the students first responded to the preexperimental questionnaire and Algebra test. When all students were finished with both parts, the form was collected and then each student received either a rule or context booklet according to which treatment group the student had been randomly assigned. Students were told that there were three sessions to the experiment and that students would be getting different instructional booklets. Students were directed to write the beginning and completion time on the booklet and to raise their hands when they finished studying the booklet so it could be collected by the proctor. When the booklet was collected, the student was given a set of mathematical puzzles (unrelated to computer programming) to solve while others finished the treatment.

On the next day of the experiment (session two) students received either a broad or narrow practice booklet or a set of mathematical puzzles according to which treatment group had been randomly assigned. Students were directed to write the beginning and completion time on the booklet and to raise their hands when they finished the booklet so it could be collected by the proctor. When the booklet was collected, the student was given unrelated mathematical puzzles to solve.

The test was administered 11 days following initial learning (session three). Students were directed to raise their hands when they finished the booklet, so that the proctor could collect it. Early finishers again were given mathematical puzzles to work on until all the students completed the test.

Results

Equality of Groups

Because a large number of students were eliminated from the original sample, an analysis was conducted to determine the equality of students between treatment groups. A one-way analysis of variance was conducted on the Algebra test scores for the six treatment groups. A test of the hypothesis yielded an F less than one.

Retention Test Score

Retention test analysis included computation of the Kuder Richardson formula 20 (KR-20) for the nine retention test items (rules). The

KR-20 reliability coefficient for the test scores was .86. An inter-scorer reliability coefficient obtained from the Pearson product moment correlation between the experimenter's test scores and an independent person's test scores was .98. To determine the effect of the independent variables (instructional context and practice variety) on the retention test scores, an analysis of variance was conducted. A two-way factorial design with two levels of one factor (instructional context) and three levels of the other factor (practice variety) was used for the data analysis. The mean scores and standard deviations for the six treatment groups are given in Table 1.

Insert Table 1 about here

The treatment effect on the retention test scores resulted in a significant $\underline{F}$ test, $p < .01$, presented in Table 2. Results indicate that there was a significant main effect, $p < .01$, for the practice variety variable, but the instructional context main effect was not significant. The results also show that the broad (BP) and narrow (NP) practice groups each scored significantly higher, $p < .01$, than the no practice groups. The instructional context by practice variety interaction was not significant.

Insert Table 2 about here

Instructional Time Score

To determine the effect of the independent variables on the instructional time, an analysis of variance was conducted. A 2X3 factorial design was used for the data analysis. The mean scores (reported in minutes) and standard deviations are presented in Table 3 for the six treatment groups.

Insert Table 3 about here

The treatment effect on the instructional time variable resulted in a significant F test, $p < .01$, as shown in Table 4. Both the instructional context and practice variety main effects were significant at the .01 level. As expected, the context groups spent significantly, $p < .01$, more time studying the instructional booklet than the rule groups. Also

Insert Table 4 about here

the broad practice groups spent significantly, $p < .01$, more instructional time than the narrow practice groups which took significantly more time than the no practice groups. The instructional context by practice variety interaction was not significant.

Discussion

Effect of Meaningful Context on Rule Retention

It was expected that a meaningful instructional context would activate a stable assimilative learning set to which the new rules could be integrated in cognitive structure. A result of this study indicated the mean difference between the context and rule groups was non-significant. In fact the rule groups scored higher on the retention test than the context groups, and took significantly less instructional time. This result in addition to the research results of other studies (Hannum, 1973; Mayer, 1975a, 1976) lead to the conclusion that the facilitating effect of a meaningful context on rule retention has not yet been established.

It was proposed in this study that meaningful instructional material for rule learning would have rule statements containing labels of concepts accessible in memory. If, however, the concept labels are not accessible, then a meaningful context would provide a set of propositions that relate the new rule to the learner's cognitive structure. A possible explanation for why the meaningful context condition in this study was not effective is that the students may have already been familiar with the concept labels in the rule statements, and therefore, the meaningful context provided no additional support in learning the rules.

Effect of the Amount and Variety of Practice Instances on Rule Retention

It was expected that providing the learner with practice instances with feedback would facilitate rule retention by causing the learner to rehearse information about the rule in short-term memory, thus allowing the long-term memory storage and retrieval processes to occur. The results of this study showed that the mean retention test performance for both types of practice groups (broad and narrow) was significantly higher than the mean performance of the no practice groups. This result supports the hypothesis that practice facilitates rule retention. This conclusion agrees with Klein's (1975) study which also found practice instances to be effective.

It was also expected that presenting a variety of practice instances during learning would further enhance rule retention by activating a broader learning set. The results of this study indicated that the difference between the mean performance scores of the broad and narrow practice groups was not significant on the retention test. Gibson (1969) found similar results which suggest that broad variation in the scope of practice instances does not facilitate rule retention. It may be that correct generalization of the concepts comprising the rule is a more critical condition for rule retention than experiencing a broad variety of rule instances.

Although the effectiveness of the meaningful context and practice variety variables on rule retention was not demonstrated in this study, a direct implication for instructional design is that the learners be given opportunities to apply the rule. A constraint during the conduct of the study necessitated the practice booklets to be administered on the second day of the experiment. It may be that the meaningful instructional context condition is an important factor only when it is immediately followed by practice instances. Another important research question asks what is the optimal number of rules that should be taught at one session, and what is the optimal amount of practice necessary for effective retention to occur? The present study taught 11 rules and provided the practice groups with 10 practice problems. Klein (1975) found that three practice instances enhanced rule retention better than one practice instance in a study that taught four rules. It may be that as the number of rules being taught increases, the amount of practice necessary to maintain a particular retention criterion must also increase. The nature of this relationship needs investigation.

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Table 1

Means and Standard Deviations of

Retention Test Scores

Instructional Context	Practice Variety: Broad Practice	Narrow Practice	No Practice
Context			
M	4.8	3.0	2.0
SD	(3.1)	(2.1)	(1.6)
Rule			
M	5.0	4.9	1.7
SD	(3.0)	(2.4)	(1.5)

Table 2

Analysis of Variance of

Retention Test Scores

Source	SS	DF	F
Treatment	214.77	5	8.27*
Instructional Context	7.73	1	1.49
Practice Variety	169.54	2	16.33*
Ho: BP=NP	12.06	1	2.32
Ho: BP=OP	153.48	1	29.56*
Ho: NP=OP	74.89	1	14.42*
Instructional Context X Practice Variety	23.47	2	2.26
Error	488.09	94	

*$p < .01$

Table 3

Means and Standard Deviations of

Instructional Time

Instructional Context	Practice Variety		
	Broad Practice	Narrow Practice	No Practice
Context			
M	49.4	39.8	19.5
SD	(8.3)	(6.6)	(5.1)
Rule			
M	43.6	31.7	14.6
SD	(7.6)	(8.2)	(4.4)

Table 4

Analysis of Variance of

Instructional Time

Source	SS	DF	F
Treatment	15627.01	5	69.70*
Instructional Context	913.04	1	20.36*
Practice Variety	15192.61	2	169.42*
Ho: BP=NP	1589.84	1	35.46*
Ho: NP=OP	5823.80	1	129.89*
Instructional Context X Practice Variety	43.76	2	.49
Error	4214.75	94	

*p < .01

Figure Caption

Figure 1. Six experimental treatment groups as assigned to the two independent variables.

Practice Variety

		BP	NP	OP
Instructional	Context	n=11	n=11	n=21
Context	Rule	n=18	n=19	n=20

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