DOCUMENT RESUME

ED 090 317 TM 003 606

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TITLE	Analytical Explantion and Task Sequence in Efficient Concept Acquisition Using Verbal and Nonverbal Tasks.
SPONS AGENCY	Office of Education (DHEW), Washington, D.C.
BUREAU NO	BR-2-D-027
PUB DATE	74
NOTE	17p.; Paper presented at the Annual Meeting of the American Educational Research Association (Chicago, Illinois, April, 1974)
EDRS PRICE	MF-$0.75 HC-$1.50 PLUS POSTAGE
DESCRIPTORS	Classification; College Students; Computer Assisted Instruction; *Concept Formation; Conceptual Tempo; Information Systems; *Instructional Design; Learning; Models; *Sequential Approach; Statistical Analysis; *Systems Approach; Task Performance; *Training

ABSTRACT

Instructional task variables of analytical explanation and sequence were studied in two experiments to assess the systems approach proposition of efficiency and effectiveness in concept learning. The independent variable of analytical explanation consisted of two components: a procedure for focusing the subject's attention on the critical attributes of the given concept, and a presentation of the strategy used to determine classification of the examples. Sequence of instances involved an organized presentation based upon the relationship of the stimulus attributes. Subjects in both experiments were college students. Organized and analytical explanation treatments resulted in less time to complete the training program, fewer errors, and less time on the posttest than the random and no analytical explanation treatments. (Author)

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Presented at the
American Educational Research Association
Annual Meeting
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Facilitation of concept learning has been demonstrated in a series of studies (Tennyson, Woolley, & Merrill, 1972; Tennyson, 1973; Merrill & Tennyson, 1971) by use of an instructional paradigm which sequences examples and nonexamples according to defined relationships of attributes and instance difficulty. The basic premise is that acquisition of a given concept can be optimized by the appropriate manipulation of task variables. These variables include: (a) display characteristics of the instances, i.e., two instances are matched when their irrelevant attributes are as similar as possible and divergent when their irrelevant attributes are as different as possible; (b) relative difficulty of the instances; and (c) additional information given to facilitate attention to relevant aspects of an instance. The objective of the concept acquisition paradigm is to insure correct classification behavior (all instances correctly identified) while preventing the errors of overgeneralization (nonexamples similar to class members identified as examples), undergeneralization (examples identified as nonexamples), and misconception (instances sharing a common irrelevant attribute(s) identified as class members).

The purpose of this study was to extend the Tennyson and Merrill concept acquisition paradigm by investigating the task variables of analytical explanation and sequence. Specifically, analytical explanation isolates critical attributes in an instance and describes a strategy for recognizing those attributes. The strategy procedure: (a) focuses attention to the critical attributes by demonstrating the divergent relationship between two examples; and (b) describes the method used to determine a given instance's classification. The second independent variable, not previously investigated in concept acquisition research, but of concern in instructional design, is sequence of instances. Assumptions of the concept model are that two examples should be simultaneously contrasted to focus on the divergency of their irrelevant attributes, and that the non-examples matched to the examples should be presented simultaneously to focus on the critical attributes.

To investigate the two defined variables of instructional design, two experiments were conducted. The first studied the analytical explanation variable, with attribute isolation only, and the sequence variable using a verbal task. Hypothesized in study one was that the additional narrative imposed by the analytical explanation would not only reduce performance errors, but also reduce time in the training program than training programs without the explanatory material. The analytical explanation variable with strategy, which specifies the relationship of the critical attributes of examples in a complex concept, was tested in the second study using a difficult nonverbal task. Inclusion of the strategy technique was hypothesized to increase the effectiveness of the concept acquisition paradigm. In both studies it was hypothesized that the organized presentation of instances would result in a significantly higher correct classification score than a random sequence of the same instances.

Experiment 1

Method

Subjects and design. Subjects (total 87) were undergraduate students from the general psychology subject pool at Florida State University. They were required to participate in an experiment for course credit. The true experimental design was a one-way analysis of covariance with a pretest/posttest. Dependent variables were error scores on the posttest and time data on the training program and tests.

Training program. The instructional objective of the training program required subjects to identify poetry selections of the concept trochaic meter. Four training programs were designed according to the two independent variables, analytical explanation and sequence. The treatment programs were: (a) organized/analytical explanation - 16 instances divided into quads of two examples (based on divergency of the irrelevant attributes, e.g., style, length, content) and two non-examples (matched to the examples by irrelevant attributes) with additional information per instance which explained the presence or absence of the critical attributes; (b) organized/no analytical explanation - same array of instances from a above, but without the additional information; (c) random/analytical explanation - instances and information used in first treatment randomized; and (d) random/no analytical explanation - instances in second treatment randomized. Each of the four training tasks included general directions on use of the computer teletype, a printed definition of the concept to which subjects could refer throughout the training program, presentation of the instances by an expository form which identified an instance as either an example or a nonexample, and the posttest on poetry identification. The instances were constantly available for comparison, since the instructional materials were presented by teletype. By the conclusion of the program, the entire array was available for further study. This particular format differed from previously cited concept studies which did not allow subjects to return to the instructional instances. The posttest was constructed to evaluate classification behavior, i.e., subjects responded to 26 previously unencountered instances. The 13 examples and 13 nonexamples were selected from the same item pool as used to construct the treatment programs.

Apparatus. The learning tasks were presented by a Digital Equipment Corporation PDP/8 680 Communication System which is interfaced to an IBM 1500 Instructional System. This system supports 16 teletypes, of which a maximum of ten were used during any one session of this study. The terminals were located in an air-conditioned, sound-deadened room. The computer-assisted instructional system administered the training program and recorded the students' responses and latencies.

Procedure. Subjects, ten at a time, were seated in the experimental room in front of a teletype. General directions were read by the experimenter, who then turned on the terminal and entered each subject's identification number. Directions on the operation of the teletype and the program were given by the computer and in a booklet. After these directions subjects were given a pretest. They were required to identify instances of trochaic poetry by typing "Yes," or "No." Following the pretest, subjects were asked if they had ever studied trochaic meter and were then instructed to read the definition of trochaic meter contained in the booklet which was kept for reference throughout the task. After studying the definition, the subjects in the analytical explanation groups were given the poetry selections labeled as examples or nonexamples, followed by the additional information. In the no information conditions, the selections were simply labeled. Following the presentation of a quad, subjects in all treatment conditions had a two-minute controlled study period, i.e., the computer would not allow continuation of the program until after the timed interval.

Each subject raised his or her hand at the conclusion of the task to indicate completion of the program. The program was nonspeeded so the subject could study at any point in the task. When the subject was ready for the posttest, the experimenter removed the task paper from the teletype, collected the definition, and entered the appropriate command to start the posttest. At the conclusion of the test the subject's correct score was given by the computer and the subject was allowed to leave.

Results

The dependent responses were analyzed according to errors on three scoring patterns: correct classification, overgeneralization, and undergeneralization. The first pattern, correct classification, represented the subjects' errors in identifying instances. Scoring patterns for the two classification errors were designed such that a positive response of a specified nonexample was considered an overgeneralization error and failure to identify a specified example was an undergeneralization error (Tennyson, Woolley, & Merrill, 1972). Time data, as a dependent variable, was collected on the pretest, the training program, and the posttest. A one-way analysis of covariance (covariates were sex and prior knowledge of trochaic meter) with a Duncan's new multiple range test were used to test each dependent variable. The data analyses are reported in two sections; the time measures and the training program error scores.

Time measures. To analyze efficiency of the two independent variables, time data were collected on the pretest, training program, and posttest. Pretest time was nonsignificant ($p > .05$); all four groups took approximately four minutes to finish the pretest. Total time spent in the training program did result in a significant difference between the four groups ($F = 2.94$, $df = 3/81$, $p < .05$) (Table 1). Duncan's test showed that the organized/analytical explanation group spent less total time on the training program than the two groups without the additional information. However, the random/analytical explanation group differed from the organized/analytical explanation group at the .08 level. On the posttest time, the organized/analytical explanation group had a significantly less time mean than the other three groups ($p < .05$). Likewise, the random group with the additional information recorded less time on the posttest than the two groups without the analytical explanation ($p < .05$).

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Insert Table 1 about here

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Training program. The statistical analysis on the pretest, consisting of 16 items given to all subjects, showed no significant difference between the four groups ($p > .05$). The pretest error means indicated minimal prior knowledge of the trochaic meter concept used in the task. Using the correct classification scores on the posttest, the four groups did perform significantly different ($F = 2.78$, $df = 3/81$, $p < .05$) (Table 1). The organized/analytical explanation group had an error mean score significantly lower from the organized/no analytical explanation group ($p < .05$) and the random/no analytical explanation group ($p < .01$);

there was no difference with the random group with additional information ($p > .05$). The other statistically significant comparison was between the two random sequence groups, with the analytical explanation group having the lower error mean score ($p < .05$). There was a difference between the two no analytical explanation groups at the .07 level.

The analysis on the overgeneralization dependent variable resulted in a significant F-test ($F = 3.09$, $p < .05$). Duncan's test showed the organized/analytical explanation group as having the lowest significant error score ($p < .05$), with no differences between the other three groups ($p > .05$) (Table 1). On the undergeneralization data analysis ($F = 2.92$, $p < .05$) the random/analytical explanation and organized/no analytical explanation groups using Duncan's test had a significantly lower score than the other random group ($p < .05$). There were no other differences ($p > .05$).

Discussion

Providing analytical explanation for the examples and nonexamples was done to focus the learners' attention on the presence or absence of the critical attributes of a given instance. Although the additional information more than doubled the amount of reading material (subjects in the conditions without additional information received only the definition of trochaic meter and the instances), the results demonstrated that the analytical-explanation condition reduced total subject time spent on the training program. Subjects in the two groups with analytical explanation not only finished the posttest in significantly less time, but they made fewer errors. This seems to indicate that the level of acquisition was better since performance was higher and required significantly less time. The treatment of organized/analytical explanation demonstrated this assumption when the subjects' posttest times were less than the random/analytical explanation, even though their posttest scores were the same. The effectiveness of this optimal treatment is shown in the overgeneralization score which demonstrated that the subjects were not making this error as did the subjects in the other groups.

An extension of the analytical explanation variable, as defined in the introduction, is inclusion of the strategy used to analyze the critical attributes of a given example in a complex concept. The second experiment, using a difficult nonverbal and noncomputerized training program, was designed to investigate the strategy technique while replicating the sequence variable using an inquisitory form of presentation.

Experiment 2

Method

Subjects and design. Students (total 155) enrolled in the core course on foundations of education at Bucknell University were used as subjects. Participation in the experiment was used to fulfill a course requirement. A posttest-only factorial design, with one main effect being three conditions of analytical explanation, and the second effect, the two levels of sequencing (organized and random), was used in this experiment.

Training program. The concept, RX_2 crystals, selected for this study had a known high level of difficult which had been obtained in a former empirical data analysis (Tennyson & Boutwell, 1973). Six training programs were designed from the independent variables of analytical explanation and sequence. Four of these programs were the same as used in Experiment 1. The two new ones were: (a) organized/strategy - in addition to the explanatory information, a strategy on how to analyze the critical attributes of a given example was provided; (b) random/ strategy - the same array as above except it was randomized. Each page of the training program consisted of two crystal pictures taken from Crystal Structures (Wyckoff, 1968). Reproductions of the pictures were made from photo copies that provided shaded crystals. Crystals were shaded so that depth perception would not confuse identification. Mode of presentation consisted of an inquisitory form which required subjects to identify an instance as either an example or nonexample. Instances were grouped into quads according to the procedures used in Experiment 1.

Procedures. Several sessions were arranged to accommodate subjects' time schedules. Subjects, seated in alternate desks in a large classroom, were each given a training program. They read the directions silently while the experimenter read aloud. Directions required each subject to identify the four crystals per quad and mark his responses on the answer sheet. Following the responses per quad, he proceeded to the next two pages to receive the given answers. The subject continued through the self-instructional task until the final quad. He was directed at that point to either return for further study or to begin the posttest. The test, in a separate booklet with an answer sheet, was administered when requested by the subject.

Results

A simplified scoring pattern was designed for analysis in this study. Correct classification remained the same, i.e., any incorrect response was an error; however, an overgeneralization error resulted from a positive response to any nonexample, while failure to identify any example was an undergeneralization error. The sum of the two error classification behaviors equals the total correct classification error score. A separate two-way analysis of variance was used for each classification error. Table 2 presents the means for the correct classification, overgeneralization and undergeneralization posttest error scores. The analysis of variance test for the undergeneralization dependent variable resulted in nonsignificance ($p > .05$) for both main effects and interaction. For correct classification scores and overgeneralization error scores, the main effects of sequence and interaction were also nonsignificant at the .05 level. Results of the correct classification analysis on the analytical explanation showed a significant difference on this variable ($F = 4.12$, $df = 2/149$, $p < .025$). The difference between means showed the two analytical explanation conditions being nonsignificant, and the no analytical explanation error mean significantly higher than the other two ($p < .05$). On the overgeneralization analysis the F-test was significant at .01 ($F = 7.92$), with the same mean relationship as the correct classification.

Insert Table 2 about here

Discussion

The purpose of the strategy/analytical explanation condition was to provide the subject with not only additional information, but also, the procedure used to identify examples of a complex concept. Previous research (Merrill & Tennyson, 1971; Tennyson & Boutwell, 1973) using the same concept had demonstrated the difficulty of classifying the RX_2 crystal pictures. If subjects were given the rationale why a particular instance was an example, it was assumed that the process would facilitate their acquisition of the concept. However, amount and type of analysis information does not seem to be directly related to the complexity of the concept. The findings showed that both analytical explanation methods resulted in significantly better performance on the posttest than the no analytical explanation, but, the manipulation of the strategy factor did not have the desired effect. Further study on analytical explanation should investigate the role of directions on strategy procedures. Subjects in all treatments received the same general directions; however, without the specific directions on use of the additional information the strategy variable might have been an overprompting situation in which the learner became bored with the increased narrative. If the directions could focus the learner on the purpose of strategy, it might be a valuable variable as shown in imagery research (Rasco, Tennyson, & Boutwell, 1973).

Summary

Instructional design methodologies assume the proposition that systematic development of content will result in both more effective and efficient learning. The concept acquisition paradigm has empirically demonstrated that learner performance can be improved by such a systems approach to design. The experiments in this study attempted to extend the Tennyson and Merrill concept model by introducing a variable to help learners analyze instances, and to test the structure of the model organization itself. The dependent variable of most concern in Experiment 1 was time on the total training program and posttest. The payoff for the proposition is that even with additional verbal information, if content is designed with systems approach variables, learning time can be significantly reduced without loss of performance.

Experiment 2 replicated the variable of analytical explanation as a factor in correct classification performance. Use of the additional analysis information to focus on critical attributes of individual instances seemed to minimize the effect of the sequence variable. In both experiments the random order of instances resulted in unanswered questions. Research here might include experimental designs to isolate the factors which seem to confound the sequence variables, e.g., instructional strategies which require learner overt responding to individual critical attributes per given instance. Further research on complex nonverbal tasks is necessary to reduce the tendency of the learner to undergeneralization, especially in conditions where additional information is provided. The level of concept acquisition in Experiment 2 leaves many design questions about complex concepts. It is obvious in such concept training programs that just an organized sequence with analytical explanation will not assure a high level of performance. Other possible independent variables are isolation of attributes, active learner participation in responding to stimuli, and imagery techniques and strategies.

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Footnotes

[1]This experiment was supported by the United States Office of Education, No. 2-D-027.

[2]Reprints may be requested from Robert D. Tennyson, Computer Applications Laboratory, Florida State University 32306.

TADLE 1

Experiment 1:

Mean Times for Training Program and Posttest; and Posttest Mean Error Scores for Correct Classification, Overgeneralization, and Undergeneralization

Independent Variables	Total Time Training Program	Time Posttest	Correct Classification	Over-generalization	Under-generalization
	Dependent Variables				
Organized/Analytical Explanation	8.3	9.1	5.4	2.3	4.6
Organized/No Analytical Explanation	10.3	13.1	7.1	4.7	3.8
Random/Analytical Explanation	9.7	11.1	6.8	4.6	3.6
Random/No Analytical Explanation	10.8	13.1	9.3	5.2	4.7

TABLE 2

Experiment 2:

Posttest Mean Error Scores for Correct Classification

Overgeneralization, and Undergeneralization

Treatments	Strategy Analytical Explanation	Analytical Explanation	No Analytical Explanation
Organized	10.1[a]	11.2	12.3
	3.9[b]	4.2	6.1
	6.2[c]	7.0	7.2
Random	11.4	10.9	13.1
	3.8	4.0	6.9
	7.6	6.9	7.2

[a]Correct classification error means.

[b]Overgeneralization error means.

[c]Undergeneralization error means.