DOCUMENT RESUME

ED 171 324 IR 007 378

AUTHOR Park, Ok-Choon; Tennyson, Robert D.
TITLE Adaptive Design Strategies for Selecting Number and Presentation Order of Examples in Coordinate Concept Acquisition.
PUB DATE Apr 79
NOTE 29p.; Paper presented at the Annual Meeting of the American Educational Research Association (San Francisco, California, April 1979)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Computer Assisted Instruction; *Concept Formation; Concept Teaching; *Educational Research; *Educational Strategies; High School Students; *Instructional Design; Mastery Learning; *Sequential Learning; Serial Ordering

ABSTRACT

A total of 132 volunteer 10th and 11th grade students participated in an experiment to investigate two variables of computer-based adaptive instructional strategies for concept learning. The first variable tested the hypothesis that selection of number of examples according to on-task information is more efficient than selection according to pre-task information or pre-task plus on-task information. Data analysis showed that the on-task information condition needed significantly less instructional time and fewer instructional examples than either of the other two conditions. The second variable contrasted response-sensitive strategy with a response-insensitive strategy to determine the presentation order of examples within rational sets. Results showed that students in the response-sensitive group not only performed better but also needed less on-task learning time and fewer examples than the response-insensitive group. (Author/CMV)

Adaptive Design Strategies for Selecting Number and Presentation Order of Examples in Coordinate Concept Acquisition

Ok-choon Park

and

Robert D. Tennyson

University of Minnesota

Paper presented at the annual meeting of the American Educational Research Association, San Fransisco, April, 1979

Adaptive Design Strategies for Selecting Number and Presentation Order of Examples in Coordinate Concept Acquisition

Abstract

Two variables of computer-based adaptive instructional strategies for concept learning were investigated. The first variable tested the hypothesis that selection of number of examples according to on-task information is more efficient than selection according to pretask information or pretask plus on-task information. Data analysis showed that for high school students, the on-task information condition needed significantly less instructional time ($p < .005$) and fewer instructional examples ($p < .001$) than either of the other two conditions. The second variable contrasted a response-sensitive strategy with a response-insensitive strategy to determine the presentation order of examples within rational sets. Results showed that students in the response-sensitive group not only performed better ($p < .005$) but also needed less on-task learning time ($p < .05$) and fewer examples ($p < .001$) than the response-insensitive group.

Adaptive Design Strategies for Selecting Number and Presentation Order of Examples in Coordinate Concept Learning

Researchers have found that student learning needs fluctuate in two important ways during instruction. First, different abilities may be required at different stages of a given task (Dunham, Guilford, & Hoepfner, 1968; Fleishman, 1967; Fleishman & Bartlett, 1969). Second, abilities may themselves change as students continue to work on a given task (Buss, 1973; Cornballis, 1965; Ferguson, 1965; Guilford, 1967). To account for these two factors in the learning environment, Bunderson and Dunham in their assessment of aptitude X interaction interaction variables (Note 1) recommended that instructional design strategies include: (a) procedures for designing the single best treatment, and (b) procedures for adjusting the best treatment, when necessary, while the student is in the process of learning.

Following this recommendation, Tennyson and Rothen (1977) investigated an adaptive instructional strategy (Rothen & Tennyson, 1978) which used both pretask and on-task diagnostic data to select the appropriate number of examples in a concept-learning task. Results showed that an adaptive instructional strategy that uses both pretask and on-task information for selecting number of instances is better then either a pretask-only strategy or a single-best-treatment strategy. In their study, as well as in other research on adaptive instruction (see Tennyson & Park, in press, for a complete review), it was assumed that the learner's on-task learning level reflected his or her updated ability on a particular unit of a given task -- an ability determined in part by prior knowledge (as measured by a pretest) and related aptitudes. However, in an instructional circumstance in which appropriate on-task information can be adequately obtained and assessed -- as in computer-based instruction -- the value of pretask data for diagnostic information should be reevaluated, especially in terms of learning efficiency (Holland, 1977).

In a review of aptitude X interaction interaction studies, Tobias (Note 2) found that where both pretask and on-task data was collected (e.g., O'Neil, Heinrich, & Hanson, 1973; O'Neil, Spielberger, & Hansen, 1969; Tennyson & Boutwell, 1973), variables measured prior to a learning task were found to be not as effective in predicting student performance as measurements taken during the task. Our purpose in this study was to extend the Tennyson and Rothen (1977) study by directly testing the effect of pretask measures against on-task measures in predicting student learning needs for a specific learning criterion. We proposed to test this effect by using two dependent measures: time required for learning and amount of instruction. Since the learning task would use the Bayesian adaptive strategy developed by Rothen and Tennyson (1978), which requires students to remain on task until they meet a given mastery criterion, performance (posttest scores) would be held as a constant. The hypothesis was as follows: An instructional treatment prescribed according to on-task information alone is more efficient (in terms of learning time and amount of instruction) than that prescribed according to pretask information or pretask plus on-task information.

Associated with the number of examples that a student needs to learn a concept is the presentation order of examples. In a recent study, C. Tennyson, R. Tennyson, and Rothen (in press), tested three patterns for sequencing examples of coordinate concepts. The results of their study showed that concept learning is more effective when concept examples are presented according to their coordinate relationships than either successively or in clusters.

Examples in the best treatment, termed simultaneous (see R. Tennyson & C. Tennyson, 1975), were grouped in the following way: within rational sets, examples had matched variable attributes and different critical attributes; between rational sets, examples had divergent variable attributes. Within rational sets, examples were also presented randomly -- that is, no attempt was made to adjust the presentation order of the examples. Thus, students continued to receive rational sets (number of examples) until they reached the mastery criterion (see Tennyson & Rothen, 1977).

A second purpose of our study was to investigate the presentation order of examples within rational sets. Our assumption was that within a rational set of examples, a classification error for one example of a given concept (undergeneralization) is an overgeneralization error for another concept in the set. Furthermore, since the learning of one concept contributes to the learning of other coordinate concepts (Tennyson & Park, in press), the correct classification of one concept example increases the possibility of correctly classifying other concept examples. Following the recommendations of Atkinson (1972) and Tennyson (1975) that presentation order of instructional stimuli be decided according to the student's response pattern during learning, a response-sensitive strategy was proposed for selecting the presentation of examples. Operationally, the response-sensitive strategy is a rule which evaluates a student's on-task responses to determine what discrimination behavior he or she should learn first. That is, if the student's classification behavior for a given coordinate concept within a rational set is correct, any other concept within the rational set can be presented next. However, if the student's classification behavior is incorrect, discrimination learning between the two confused concepts would be facilitated by next presenting the concept for which the overgeneralization error was made. For example, if the student classified concept A as concept B, concept B would be presented next. If the instruction were to continue without facilitating discrimination between the two concepts, the ensuing confusion would interfere with not only the learning of the two concepts but also with the learning of other coordinate concepts. In other words, since the learning of coordinate concepts occurs simultaneously, the learning of one concept contributes to the learning of all others (C. Tennyson et al., in press). The response-sensitive strategy thus differs from the sequencing procedures used in previous concept learning research (e.g., Klausmeier & Feldman, 1975; Sanders, DiVesta, & Gray, 1972; Stolurow, 1975; Tennyson & Rothen, 1977) in that the succeeding example is presented in reference to the classification of the response rather than to a predetermined (response-insensitive) sequence of instances. To test this independent variable of presentation order, we contrasted the response-sensitive procedure with the response-insensitive procedure and hypothesized that the former procedure would be both more effective (posttest performance) and efficient (time on task) in student learning than the latter.

Method

Students and Design

Participants (N = 132) were 10th and 11th grade male and female volunteers from a Minnesota high school enrolled in social study classes. From a random list of the six treatment conditions, students were assigned one treatment condition as they appeared for the experiment. The students understood that they could discontinue participation without prejudice at any time during the experiment. A two-way experimental design was used with multivariate analysis of variance. The first factor, information, had three levels: pretask (number of examples determined by pretest performance), on-task (number of examples determined by learning task performance); and, pretask plus on-task (number of examples determined by pretest performance and updated learning task performance). The second factor, presentation order, had two levels: response-sensitive (selection of examples within rational sets by a rule using as data individual student response patterns) and response-insensitive (sequence of examples within rational sets predetermined by experimenter -- a random order). Dependent variables were the correct posttest scores, learning task time, total program time (pretest time plus learning task time), number of task examples, and total number of program examples (pretest examples plus task examples).

Learning Program

The coordinate concepts selected for this study -- drawn from the field of psychology and developed by C. Tennyson, R. Tennyson, and Rothen (in press) -- were positive reinforcement, negative reinforcement, positive punishment, and negative punishment. Subordinate concepts consisted of stimulus, aversive stimulus, and attractive stimulus; and a superordinate concept dealt with the consequences of behavior resulting from the stimulus. An assumption of the coordinate concept structure is that when several concepts of a content taxonomy are taught concurrently, the nonexamples of any one concept are the examples of other concepts of the taxonomy (Klausmeier, 1976; Merrill & Tennyson, 1977). This allows the defining critical attributes of the taxonomy to be standardized and the variable attributes to be manipulated in both examples and nonexamples in such a way as to focus on the critical attributes -- which include such factors as degree of instance difficulty, relative importance of the variable attributes, and cause and effect relationships (Klausmeier et al., 1974;

Klausmeier, 1976; C. Tennyson et al., in press). Therefore, to establish the critical attributes of the four psychological concepts and to place the definitions in an algorithmic framework, we presented the three subordinate concept definitionsprior to the definition of the coordinate concepts.

Of 88 examples in the learning program, 40 were used in the instructional lessons, 24 in the pretest, and 24 in the posttest. Six examples of each concept were given for each test (Woolley & Tennyson, 1972). The instructional instance pool contained 10 instances of each concept. Thus, at maximum, a student could receive 64 instances before taking the posttest. Since each example contained two lines, all of the instances were parallel in length and arrangement. Each treatment group employed the same instance pool. The learning program retained the same response format as the two tests, except that in the learning program the student received feedback on whether or not the entered response was correct. The learning program was validated and revised according to a formative evaluation procedure for instructional materials (Tennyson, 1976).

Bayesian Probability Model

To study the first variable -- information used in determining number of examples -- we applied a computerized Bayesian statistical model developed by Rothen and Tennyson (1978). This model determines the number of instances which each student receives from three parameter values: achievement level, a mastery criterion (.7), and loss ratio (1.5) -- which is defined as the disutilities associated with a false advance compared to a false retain decision. The estimate of the student's ability to learn a concept was characterized in probabilistic terms. The probability calculated from the initial achievement level and the other two parameter values was used to decide the initial number of instances that the student needed. The initial achievement level was determined according to the pretest score, or, if the student did not receive the pretest, the score of the first six instructional items of the on-task learning program. This probability figure was adjusted according to the student's on-task performance level, and the prescribed number of instances was modified -- unless the students were in the condition for which the number of instances was prescribed according to the pretask information only. Student performance on each concept was calculated separately with a criterion level set at 1.0 on the initial assessment. That is, if the student answered all six instances of any concept correctly on the pretest or the initial part of the learning program, he or she received no more examples of that concept. In the response-sensitive treatment, however, the student received more examples of the concept even after reaching the criterion if these were needed for discriminating coordinate concepts.

If the student did not achieve total mastery on the initial assessment, the criterion level was adjusted to suggest a prior distribution slightly greater than .5 to the region above the criterion level: $P = (\pi \geq \pi_o / \underline{x}, \underline{n}) > .5$ (where π_o is the objective's criterion level, π is the student's true achievement level, $\underline{n}$ is test length, and $\underline{x}$ is the student's score). Complete descriptions of the Bayesian adaptive model are presented in Rothen and Tennyson (1978) and Tennyson and Rothen (1977).

Treatment Programs

The two independent variables of information (three conditions: pretask information, on-task information, and pretask plus on-task information) and presentation order (two conditions: response-sensitive and response-insensitive) were tested with a two-way factorial design and six treatments. Pretask information was determined from the pretest score according to the Bayesian probability model, and the pretest score was translated into a probability showing prior achievement level. From the probability of the prior achievement level, the necessary number of examples was selected.

On-task information was taken from the performance level during the instruction. Because performance level was continuously evaluated with each response, the updated probability of mastery level during instruction was provided by continuous prior and posterior probability distribution of Bayes's theorem. The necessary number of examples was selected initially from the on-task performance level on the first six items per concept. The initially selected number of examples was continuously modified according to the updated performance level until either the performance level reached the criterion level or all examples in the pool were presented.

The third condition -- pretask plus on-task information -- was provided from both the pretest score and on-task performance level. After the necessary number of examples was initially selected by the pretest score, it was continuously modified by the on-task performance level. Modification of the selected number of examples was continued until either the performance level reached the criterion level or all examples in the pool were presented.

The selected number of examples was presented in rational sets consisting of one example from each concept. Within a rational set, as stated, the representative examples had matched variable attributes and different critical attributes; between sets, the examples had divergent variable attributes.

The second independent variable studied was presentation order of examples within the rational sets. The response-sensitive strategy determined this presentation order according to the student's response pattern to the given example. For instance, if the student correctly classified an example of concept A, the next example was randomly selected from other concepts within the rational set which had not yet been presented. However, if the student classified the concept A example as concept C, an example of concept C followed immediately thereafter. If the student classified the concept C example as belonging to concept B -- of which an example within the rational set had not been presented -- an example of concept B followed immediately thereafter. However, if the concept B example within the rational set had already been presented, the student was given the concept B example again with the following message: "You needn't answer this question because you have studied it before." Then an example of another concept within the set was presented.

Because the response-sensitive strategy attempted to assist discrimination of concepts, the examples of the concept were presented again whenever they were needed for discrimination learning between that concept and the others -- even after a student's performance level for a concept reached the criterion level. For example, if a student classified an example of concept B as belonging to concept A -- which had been judged to have already been mastered -- the example of concept A was presented again to facilitate the discrimination learning between concepts B and A. Although the student incorrectly classified the example of the concept presented for discrimination learning after the mastery decision for that concept had been made, the mastery decision was not reassessed.

The response-insensitive strategy presented examples randomly within rational sets (C. Tennyson, R. Tennyson, & Rothen, in press). When a student's performance level reached the criterion level for any given concept, examples of that particular concept were dropped from succeeding rational sets. The six computer-based instructional treatment programs developed from the above described conditions were as follows:

Program 1. The number of examples in this treatment was selected from the pretest score only (pretask information). The presentation order of the selected number of examples was response-sensitive within the rational sets.

Program 2. The number of examples was selected according to student on-task performance level (on-task information). The presentation order of the examples within a rational set was response-sensitive.

Program 3. After the number of examples was initially selected from the pretest score, it was adjusted according to on-task performance level (pretask plus on-task information). The presentation order was response-sensitive.

Program 4. The necessary number of examples per concept was selected from the pretest score of each concept (pretask information). The examples within a rational set were presented using the response-insensitive condition.

Program 5. The necessary number of examples was selected from on-task performance level (on-task information). The presentation order of the examples within the rational sets was response-insensitive.

Program 6. After the necessary number of examples was selected from the pretest score, it was adjusted according to the on-task performance level (pretask plus on-task information). The response-insensitive procedure was used.

Facilities

The experiment was conducted in the social studies teachers' conference room at Minnetonka Senior High School, Hopkins, Minnesota. Three Texas Instrument teletype computer terminals (700 series) were used for the study. Each terminal, operating at 30 characters per second, was on-line by telephone to the University of Minnesota's Control Data 6400 Computer.

Procedure

As students reported for the experiment, they were each assigned to a treatment program from a random list of six treatments. The experimenter turned on the terminal and entered each student's treatment program number. After receiving directions on operating the terminal, students were administered the pretest. Students in the on-task information groups (Programs 2 and 5), who had not taken the pretest, received a 30-item syllogism test (French, Ekstrom, & Leighton, 1963). When the pretest (or syllogism test) was finished, students were individually directed to raise their hands to get a print copy of the four concept definitions from the experimenter; they were able to refer to these definitions during the learning program. After studying the definitions, students again raised their hands to indicate readiness to study the examples in the learning program. The experimenter entered the appropriate command on the terminal for students to begin the learning program. The number of examples presented in the learning program varied depending upon the treatment program to which each student was assigned. After a student classified an example in the learning program, he or she received feedback on whether the classification was correct or incorrect. When each student was finished with the learning program, the experimenter took the definition sheet and entered the appropriate command on the terminal for the posttest to begin. All student entries were single-letter alphanumeric responses to multiple-choice styled questions. The two tests and the learning program required no other entries by the students. When finished, students were thanked by the experimenter, left the experiment room, and others were signed on to the terminal.

Results

The data analysis consisted of a multivariate analysis of variance with univariate tests on each dependent variable followed by mean comparison tests

(Student-Newman-Keuls). Dependent variables included the correct score on the pretest, task time (the measured time period in which students interacted with the learning task, excluding pretest or posttest times), total program time (this measure included the task time and the time required for the pretest), number of task examples (the number of examples presented to the students in the learning task), and the total number of program examples (the number of examples required in the learning task plus pretest items). For clarity, discussion of the independent variable of presentation order (response-sensitive and response-insensitive) will be given first, followed by discussion of the information variable (pretask information, on-task information, and pretask plus on-task information).

For the multivariate test, we used as dependent variables posttest score and total program time. The main effect of presentation order was significant, $\underline{U}(1, 1/2, 130) = .84$, $\underline{p} < .001$. The test on the second main effect, information, was likewise significant, $\underline{U}(2, 0, 129) = .36$, $\underline{p} < .001$. The interaction test between the two independent variables was nonsignificant ($\underline{p} > .05$). Following are the univariate test results on each of the dependent variables.

Posttest Correct Score

The analysis of variance test on the posttest correct score (Table 1) showed a difference between the two presentation orders, $F(1, 126) = 10.53$, $\underline{p} < .001$. Students in the response-sensitive condition ($\underline{M} = 19.0$) had a posttest score of two points higher than students in the response-insensitive condition ($\underline{M} = 16.6$). For the main effect of information, the $\underline{F}$ test was nonsignificant at the .05 level. The Student-Newman-Keuls multiple range test was used to compare posttest correct mean score differences between the six treatment groups. At the .05 level, Group 3 (pretask plus on-task information/response-sensitive) had a higher posttest score than the other five groups, while Group 4 (pretest information/response-insensitive) and Group 6 (pretask plus on-task information/response-insensitive) had significantly lower posttest scores than the other groups. The χ^2 test was used to determine differences between the six treatment programs in the number of students who reached mastery criterion (.7) on the posttest. The difference was significant, $\chi^2(5) = 13.37$, $p < .05$, indicating that more students reached mastery in the response-sensitive condition than in the response-insensitive condition. The pretest correct mean score F test was nonsignificant ($p > .05$).

Insert Table 1 about here

Time

The average time spent on the pretest and posttest was the same ($M = 8.7$ min.). There were no significant differences between groups for the pretest time or the posttest time ($p > .05$). Task time was different for the two presentation order conditions, $F(1, 126) = 5.34$, $p < .05$ (response-sensitive, $M = 12.2$ min.; response-insensitive, $M = 14.1$ min.) (Table 2). However, on total program time, including pretest time with task time, there was no difference between the two conditions ($p > .05$).

Insert Table 2 about here

The univariate test on the information main effect for task time was significant, $F(2, 126) = 23.4$, $p < .001$ (Table 2). A contrast test between the three conditions, on-task information ($M = 17.1$) versus pretask information ($M = 12.0$) and pretask plus on-task information ($M = 10.5$), resulted in a difference, $F(1, 126) = 15.07$, $p < .001$; the contrast test between the pretask information and pretask plus on-task information conditions was nonsignificant ($p > .05$).

The F test on the three information conditions for total program time was significant, $F(2, 126) = 4.52$, $p < .05$. Two contrast tests were conducted to compare total program time: First, the on-task information condition ($M = 17.1$) was contrasted with the pretask information condition ($M = 20.7$) and pretask plus on-task information condition ($M = 19.2$); results showed that the on-task information condition used less total program time, $F(1, 126) = 12.67$, $p < .005$. The second contrast test between the two latter conditions was nonsignificant ($p > .05$). A Student-Newman-Keuls test on the six group means for total program time showed that Group 2 (on-task information/response-sensitive) spent less time totally than the other five groups. The two pretask information groups (Group 1, response-sensitive and Group 4, response-insensitive) averaged more total program time than Groups 2, 3, and 5 ($p < .05$). Group 6 (pretask plus on-task information/response-insensitive) differed only with Group 2 (on-task information/response-sensitive).

Number of Examples

The mean and standard deviations for number of examples required by students for the learning task and learning task plus pretest are given in Table 2. The analysis of variance test on number of task examples for the presentation order main effect was nonsignificant ($p > .05$). However, on total number of program examples, the F test showed a difference between the response-sensitive condition ($M = 36.7$) and the response-insensitive condition ($M = 39.7$), $F(1, 126) = 12.38$, $p < .001$. For the second main effect, information, the univariate test on a number of task examples showed a difference between the three condition means, $F(2, 126) = 56.39$, $p < .001$. The contrast tests showed that the students in the on-task information condition (M = 29.8) needed more examples during the learning task than student in either the pretask information (M = 19.3) and pretask plus on-task information conditions (M = 17.5), $F(1, 126) = 81.59$, $p < .001$. The difference between the two former conditions on the second contrast test was nonsignificant ($p > .05$). Total number of program examples as a dependent variable showed (univariate test, $F(2, 126) = 99.95$, $p < .001$), in the contrast test, that the on-task information condition (M = 29.8) had fewer examples than the pretask information (M = 43.3) and pretask plus on-task information (M = 44.5) conditions. The findings here are consistent with the time data. That is, students in the on-task information condition needed an average of 11.4 more examples on the learning task than those in either the pretask information or pretask plus on-task information conditions. However, the total number of examples -- including pretest and learning task -- needed for the on-task information condition was 12.6 less than the other two information conditions. The Student-Newman-Keuls multiple range test (at .05 level) for the total number of program examples showed that the mean number for Group 2 (on-task information/response-sensitive) was significantly lower than the other five groups while the mean number of Group 4 (pretask information/response-insensitive) was significantly higher than the other five groups, and the mean number of Group 5 (on-task/response-insensitive) was significantly higher than that of Group 2 but lower than the other four groups.

Discussion

Our first hypothesis -- testing the information variable -- was concerned with program learning efficiency rather than performance outcomes. Results of this experiment confirmed our thesis. First, for both time (task time and total program time) and number of examples (number of task examples and total number of program examples), the on-task information condition was significantly better than the other two conditions; second, since all conditions used the Bayesian adaptive strategy, only one group failed to reach the mastery criterion of .7 (and that at 67 percent). Thus, performance was basically the same for the three information conditions.

Following procedures developed by Tobias (1976) and others (Frase, 1970; Hartley, 1973; Hartley & Davis, 1976; Rothkopf, 1970), we included the pretest data, time, and number of examples as part of the learning program's dependent variables. That is, the pretest seems to serve as an alerting function by increasing student sensitivity to a learning situation; it may alert them to issues, problems, or events that they may not have ordinarily noticed. The results showed that the pretest does influence learning task time (by decreasing it) and number of task examples (again, by decreasing it); overall, however, the total time spend by the student is increased significantly (along with total instructional stimuli needed) without improvement in posttest performance. This finding is consistent with the earlier Tennyson and Rothen (1977) study in which the posttest performance of students who received more examples was lower than that of students who received fewer examples. Tennyson and Rothen's interpretation of that finding was that the students who received more examples lost interest in the learning task, with corresponding decrease in performance. Both this study and Tennyson and Rothen (1977) contradict studies which indicate that repetition increases the level of learning (e.g., Ausubel, Robbins, & Blake, 1957; Ausubel, Strager, & Gaite, 1968; Lumsdaine, Selzer, & Kopstein, 1961). According to these studies, as the number of examples is increased, the level of learning increases correspondingly. These earlier research efforts, however, looked at students as a group rather than as individuals. What the findings here seem to indicate is that on-task information is more accurate than pretask information in predicting the number of examples needed by students to reach mastery, and the instructional treatment prescribed by on-task information is also more efficient in total time required by the students than either the pretask information or pretask plus on-task information procedures.

In the study of the second independent variable, presentation order, we hypothesized that the response-sensitive procedure would be more effective than the response-insensitive procedure because the latter presentation order focused the student's attention directly on the different critical attributes between concepts according to the priority of the student's learning needs (especially discrimination learning). Because generalization learning and discrimination learning occur simultaneously (Klausmeier, 1976; Markle, Note 2), and learning of one concept contributes to learning of other related concepts (Markle, Note 2; C. Tennyson et al., in press), it was expected that discrimination learning between concepts by the response-sensitive presentation order facilitated not only generalization learning within concepts but also discrimination learning between all the coordinate concepts in the set. Students in the response-sensitive group were not only significantly better on posttest performance, they also finished the learning program with fewer examples and in less time than the response-insensitive group. Of students in the response-sensitive group, 83 percent obtained the mastery criterion level (.70), while 64 percent of the students in the response-insensitive group obtained criterion. The prior expectation of mastery on which the Bayesian prior probability distribution was made was that 70 percent of students would reach the criterion level. In the response-insensitive group, once the student reached the criterion level for any concept, the examples of that concept were no longer presented -- even though he or she needed to discriminate between that concept and the others. This procedure failed to present some necessary examples for discrimination learning, and it resulted in a lower performance level on the posttest. In the response-sensitive group, however, a concept was presented again whenever it was needed, even after the student reached the criterion level. As a result of this flexible presentation procedure, a higher percentage of students in the response-sensitive group than in the response-insensitive group reached the mastery level. Additionally, the standard deviations of posttest scores showed less disparity among students for the response-sensitive group (SD = 2.7) than for the response-insensitive group (SD = 4.0). Theoretically, the response-sensitive strategy would require more examples than the response-insensitive strategy because examples were presented for discrimination learning even after the mastery decision for the concept had been made. However, students in the response-sensitive group needed significantly fewer examples to learn the set of coordinate concepts and showed significantly higher posttest performance than students in the response-insensitive group. This result demonstrated the effectiveness of the response-sensitive strategy.

Because the response-sensitive strategy determined presentation order of the examples according to the priority of individual student's need to discriminate between two particular concepts, the presented examples contributed more to learning especially to discrimination learning than examples which failed to consider the priority of the student's learning needs.

Implications of this study, when taken in reference to our previous work (e.g., Tennyson & Rothen, 1977; C. Tennyson, R. Tennyson, & Rothen, in press) are as follows: (a) on-task information seems to provide the best data for adjusting instruction to individual needs -- moreso than pretask information (e.g., aptitude X treatment interaction variables); (b) use of the pretest as part of the instructional program does not seem efficient -- in fact, it may increase total time and thus contribute to student dissatisfaction (boredom) with the learning task; (c) the instructional principle that increased examples may increase learning may be questioned; since the number of examples is primarily an individual need, simply increasing examples may actually decrease performance; and (d) a response-sensitive strategy in reference to error pattern will improve performance, decrease learning time, and reduce the amount of instruction necessary.

Note References

1. Bunderson, C. V., & Dunham, J. L. Research program on cognitive abilities and learning. Final Report, Advanced Research Projects Agency, Contract No. 0014-A-016-0006. Austin, Texas, University of Texas, 1970.

2. Tobias, S. Interaction between achievement and instructional method. Paper presented at the annual meeting of the American Educational Research Association, Toronto, Canada, March, 1978.

3. Markle, S. M. Teaching conceptual networks. Paper presented at convention of the Association for Educational Communications and Technology, Miami, April, 1977.

References

Atkinson, R. C. Ingredients for a theory of instruction. American Psychologist, October, 1972, 27, 921-931.

Ausubel, D. P., Robbins, L. C., & Blake, E. Retroactive inhibition and facilitation in the learning of school materials. Journal of Educational Psychology, 1957, 48, 334-343.

Ausubel, D. P., Stager, M., & Gait, A. J. H. Retroactive facilitation in meaningful verbal learning. Journal of Educational Psychology, 1968, 59, 250-255.

Buss, A. R. Learning, transfer, and changes in ability factors: A multivariate model. Psychological Bulletin, 1973, 80, 106-112.

Cornballis, M. C. Practice and the simplex. Psychological Review, 1965, 72, 399-406.

Dunham, J. L., Guilford, J. P., & Hoepner, R. Multivariate approaches to discovering the intellectual components of concept learning. Psychological Review, 1968, 75, 206-221.

Ferguson, G. A. Human abilities. Annual Review of Psychology, 1965, 16, 39-62.

Fleishman, E. A. Individual differences in motor learning. In R. M. Gagné (Ed.), Learning and individual differences. Columbus, Ohio: C. E. Merrill Books, 1967.

Fleishman, E. A., & Bartlett, C. J. Human abilities. Annual Review of Psychology, 1969, 20, 349-380.

Frase, L. T. Boundary conditions for mathemagenic behaviors. Review of Educational Research, 1970, 40, 337-348.

French, J. W., Ekstrom, R. B., & Leighton, A. P. Manual for kit of reference tests for cognitive factors. Princeton, N.J.: Educational Testing Service, 1963.

Guilford, J. P. The Nature of human intelligence. New York: McGraw-Hill, 1967.

Hartley, J. The effect of pre-testing on post-test performance. Instructional Science, 1973, 2, 193-214.

Hartley, J., & Davis, I. K. Pre-instructional strategies: The role of pre-tests, behavioral objectives, overviews, and advance organizers. Review of Educational Research, 1976, 46, 239-265.

Holland, J. P. Variables in adaptive decisions in individualized instruction. Educational Psychologist, 1977, 12, 146-161.

Klausmeier, H. J. Instructional design and the teaching of concepts. In J. R. Levin & V. L. Allen (Eds.), Cognitive learning in children. New York: Academic Press, 1976.

Klausmeier, H. J., & Feldman, K. V. Effects of a definition and a varying number of examples and nonexamples on concept attainment. Journal of Educational Psychology, 1975, 67, 174-178.

Klausmeier, H. J., Ghatala, E. S., & Frayer, D. A. Conceptual learning and development: A cognitive view. New York and London: Academic Press, 1974.

Lumsdaine, A. A., Sulzer, R. L., & Kopstein, F. F. The effect of animation cues and repetition of examples on learning from an instructional film. In A. A. Lumsdaine (Ed.), Student response in programmed instruction. Washington, D.C.: National Academy of Science--National Research Council, 1961.

Merrill, M. D., & Tennyson, R. D. Teaching Concepts: An instructional design guide. Englewood Cliffs, New Jersey: Educational Technology, 1977.

O'Neil, H. F., Jr., Heinrich, D. L., & Hansen, D. M. Effect of anxiety, response mode, and program length on achievement. Journal of Educational Psychology, 1973, 64, 310-324.

O'Neil, H. F., Jr., Spielberger, C. D., & Hansen, D. M. The effects of state-anxiety and task difficulty on computer-assisted instruction. Journal of Educational Psychology, 1969, 60, 343-350.

Rothen, W., & Tennyson, R. D. Application of Bayes's theory in designing computer-based adaptive instructional strategies. Educational Psychologist, 1978, 12, 317-323.

Rothkopf, E. Z. The concept of mathemagenic behaviors. Review of Educational Research, 1970, 40, 325-336.

Sanders, N. M., DiVesta, F. J., & Gray, G. S. Effects of concept instance sequence as a function of stage of learning and learner strategy. Journal of Educational Psychology, 1972, 63, 235-241.

Stolurow, K. A. C. Objecitve rules of sequencing applied to instructional materials. Journal of Educational Psychology, 1975, 67, 909-912.

Tennyson, C. L., Tennyson, R. D., & Rothen, W. Content structure and management strategy as design variables in concept acquisition. Journal of Educational Psychology, in press.

Tennyson, R. D. Adaptive instructional model for concept acquisition. Educational Technology, 1975, 15(4), 7-15.

Tennyson, R. D. The role of evaluation in instructional development. Educational Technology, 1976, 16, 17-24.

Tennyson, R. D., & Boutwell, R. C. Pre-task versus within-task anxiety measures in predicting performance on a concept acquisition task. Journal of Educational Psychology, 1973, 65, 88-92.

Tennyson, R. D., & Park, O. The teaching of concepts: A review of instructional design research literature. Review of Educational Research, in press.

Tennyson, R. D., & Park, O. The technology of adaptive instruction. Review of Educational Research, in press.

Tennyson, R. D., & Rothen, W. Pretask and on-task adaptive design strategies for selecting number of instances in concept acquisition. Journal of Educational Psychology, 1977, 64, 586-592.

Tennyson, R. D., & Tennyson, C. L. Rule acquisition design strategy variables: Degree of instance divergence, sequence, and instance analysis. Journal of Educational Psychology, 1975, 67, 852-859.

Woolley, F. R., & Tennyson, R. D. Conceptual model of classification behavior. Educational Technology, 1972, 12(4), 37-39.

Table 1

Means and Standard Deviations

for Posttest Correct Scores

Presentation Order	Information		
	Pretask	On-Task	Pretask/On-Task
Response-sensitive			
M	18.0	18.7	20.2
SD	3.5	2.5	1.8
Response-insensitive			
M	16.0	17.0	16.9
SD	4.6	3.6	3.6

Note: Maximum posttest score = 24.

Table 2

Mean and Standard Deviations

for Amount of Time and Number of Examples

Presentation Order	Information					
	Pretask		On-Task		Pretask/On-Task	
	Task	Total	Task	Total	Task	Total
	Amount of Time (Min.)					
Response-sensitive						
M	11.4	20.4	15.9	15.9	9.4	18.5
SD	3.9	5.4	6.4	6.4	1.9	4.4
Response-insensitive						
M	12.6	20.9	18.2	18.2	11.5	19.8
SD	3.3	4.6	5.7	5.7	4.9	5.7
	Number of Examples					
Response-sensitive						
M	17.6	41.6	27.8	27.8	16.7	40.7
SD	4.8	4.8	3.2	3.2	2.2	2.2
Response-insensitive						
M	21.0	45.0	31.7	31.7	18.3	42.3
SD	5.1	5.1	4.6	4.6	7.1	7.1

Note: The on-task information condition did not receive the pretest; thus, means and standard deviations for task and total are the same.