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ABSTRACT

This study tested the hypothesis that high school students can effectively manage their learning needs in a computer-assisted instructional system when provided on-task advisement of their learning achievement in relation to a given criterion. One hundred and thirty-nine male and female high school students from a 12th grade course in psychology were assigned randomly to one of four treatment conditions. The two independent variables of management strategy (adaptive control and learner control) and advisement (with and without) were tested with a pretest-posttest, two-way factorial design that involved the four treatment groups. Advisement information was provided to the students using the Minnesota Adaptive Instruction System. Data analysis indicated that advisement, using either a program control or learner control management strategy, resulted in better posttest performance, less instructional time, and fewer instructional examples than those same management strategies with no advisement. (Author/MER)

Advisement and Management Strategies

as Design Variables in Computer-Assisted Instruction

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Advisement and Management Strategies as Design Variables in Computer-Assisted Instruction

Control of the amount and sequence of instructional stimuli has been a recurring problem in the design of computer-assisted learning environments. Methods of control have ranged from those in which the learner plays a direct role in decision-making to more highly sophisticated adaptive systems (Tennyson & Rothen, 1979). The adaptive systems include processes for assessing both the student's skills (for example, general aptitudes, prior achievement, on-task learning progress) and the characteristics of the learning task (difficulty level, content structure, conceptual attributes) so that an initial instructional program can be continuously adjusted to meet on-task student learning needs. However, instructional research (DiVesta, 1975) and applied projects (Steinberg, 1977) dealing with variables of learner control (using rather large or complex learning tasks) have failed to demonstrate that students can make and carry out decisions of content element selection and personal assessment. It would therefore appear that program controlled management systems are necessary for effective computer-assisted instruction.

Given poor student performance with learner control systems consisting of a complex content structure and demanding greater prerequisite knowledge, Tennyson and associates designed (Rothen & Tennyson, 1978) and tested (Park & Tennyson, in press; Tennyson & Rothen, 1977; Tennyson, Tennyson, & Rothen, in press) the Minnesota Adaptive Instructional System (MAIS), which uses a Bayesian statistical method to integrate (a) assignment of a specific treatment based on a premeasure of cognitive ability; (b) an initial amount of instructional support based on a pretest measure of prior achievement; and (c) adjusted amount of instructional support and sequence based on on-task learning need. Our first purpose in this study was to test the MAIS against a learner control strategy (one in which the student decides when to terminate instruction and begin the posttest). Based on the findings of the Tennyson and Rothen (1977) study, which showed that the MAIS management strategy was significantly more effective than a nonadaptive management strategy, we hypothesized that adaptive control would be more effective than learner control in helping students to learn concept tasks.

While adaptive control systems do make use of modern computing power (Johansen & Tennyson, in press), they do not take into consideration the educational goal of individual responsibility for learning and consequent intellectual development. To address this goal, instructional program strategies have attempted to provide students with post hoc advice about possible remedial instructional help (Bunderson, Note 1). We propose, however, that if students are given meaningful information (advisement) on-task about their own learning development, their own cognitive strategy may further refine the diagnosis and prescription made by an adaptive management system. Thus, advisement as used in this study is a form of information that consists of diagnostic and prescriptive data generated from the MAIS management control system and given to students during the learning process. Operationally, advisement implies several things. First, at the start of their instruction, students are advised of (a) their initial level of knowledge compared to the desired learning criterion (diagnosis), and (b) the amount and sequence of instruction necessary for them to obtain the objective (prescription). Second, students are continuously advised while on-task of their learning development (updated diagno... ...nd the instructional needs (updated prescription) necessary for task mastery.

For the independent variable of advisement, we hypothesized that student performance with advisement would be improved over a conventional computer-assisted instructional program that lacked advisement. We further hypothesized that a learner control strategy with advisement would not only be as effective in student acquisition of the learning task as the adaptive control strategy (that is, students in both these strategy conditions would surpass the criterion of mastery) but also that it would be more efficient in terms of student on-task learning time. An additional hypothesis was that the interaction of learner control with advisement would be the best treatment (of the four treatment conditions resulting from the two independent variables) in terms of both performance and time on-task, whereas the learner control without advisement condition would be the least effective (that is, students would not reach mastery).

Method

Subjects

Participants (N = 139) were twelfth grade male and female students from a psychology class at Eisenhower Senior High School in Hopkins, Minnesota. Students were assigned randomly to one of four treatment conditions as they appeared for the experiment. They understood that they would be given credit for participation and that their teacher would grade their posttest scores. This contingency was included to stimulate an actual classroom-related incentive missing from most learner control studies. Without such a contingency, as Felixbrod and O'Leary (1974) have shown, students in learner control stituations tend to terminate early and thus learn less.

A strong incentive to master the material -- in this instance, a course grade -- provides a better comparison between a program control condition, which relies on a relatively captive audience, and a learner control condition.

Learning Program

Coordinate concepts selected for this study -- positive reinforcement, negative reinforcement, positive punishment, and negative punishment -- were drawn from the field of psychology (Tiemann, Kroecker, & Markle, Note 2) and developed by Tennyson, Tennyson, and Rothen, (in press). Three subordinate concepts -- stimulus, aversive stimulus, and attractive stimulus -- were included, in addition to a superordinate concept that dealt with the consequences of behavior resulting from the stimulus. Examples used in the learning program and accompanying tests were written according to the concept design strategy developed by Merrill and Tennyson (1977). Of 88 examples in the learning program, 40 were used in the instructional lessons (10 per concept), 24 in the pretest, and 24 in the posttest.

Using Tennyson's (in press) revision of the Merrill and Tennyson (1977) procedures for designing concept learning lessons, the experimental learning program was developed. First, a printed booklet presented the instructional directions and the concept definitions with one prototype example per concept. The directions explained that the purpose of the definitions was to help the student understand the critical attributes of each concept, whereas the prototypes were to be used during the instructional presentation to compare and contrast with the instructional examples. Second, a computerized instructional program presented the examples in two presentation forms -- expository and inquisitory (Tennyson, Chao, & Youngers, in press). In the expository presentation form, one example of each concept was displayed and students were directed to study how each of these examples differed from the prototype examples. After studying the four expository examples, students received their remaining examples in the inquisitory presentation form. Directions for the inquisitory presentation from instructed students to use the prototype examples when determining the correct classification of each example. (This procedure helps a student learn to use the prototype in developing the intellectual skills of generalization and discrimination.) After each response, students received confirmation on whether their answer was correct or incorrect. Students in the two advisement groups also received an update on the number of examples still needed for mastery.

To validate the learning program, we used a formative evaluation procedure for assessing instructional materials (Tennyson, 1978). Several subject matter experts first reviewed the definitions and instances. Then, after appropriate revisions of the definitions and instances, a one-to-one tryout of each learning program was conducted with six randomly selected students from the sample population. This was followed by simulation tryouts of each treatment condition (six students per treatment). Final refinements on the learning program and computer software were made from this tryout.

Minnesota Adaptive Instructional System

To study the management strategy variable, we used for the adaptive control strategy the computer-based Minnesota Adaptive Instructional System developed by Rothen and Tennyson (1978). This computer management system determines the number of examples 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. From the initial achievement level, which was determined by the pretest score and the other two parameter values, the probability was used to decide the initial number of examples per concept that the student needed. This probability figure was adjusted according to the student's on-task performance level, then the prescribed number of examples was modified. 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 examples 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 unless it was needed for discriminating coordinate concepts. (For a complete review of this response-sensitive procedure, see Tennyson and Park, 1980; or Park and Tennyson, in press.) If the students failed to 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_c 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 (Tennyson & Rothen, 1979).

Treatment Programs

The two independent variables of management strategy (adaptive control and learner control) and advisement (with and without) were tested with a pretest-posttest, two-way factorial design that involved four treatment groups. In the adaptive control strategy, the number of instances presented to each student was based on the student's pretask and on-task performance in relationship to the learning objective, and the sequence of instances was presented according to the student's response pattern to the given example. Following the pretest, students in the adaptive control condition were given program directions and informed that they would receive a posttest at the conclusion of the instruction. In the learner control strategy, the students themselves decided whether to continue receiving examples (and if so, which concept they wanted to see next) or to go to the posttest. Students were informed in the program directions that they had complete control on the amount and sequence of instruction.

For the second independent variable, advisement, the two conditions (with and without advisement) were operationally designed as follows: in the advisement condition for adaptive control, students were informed, following the pretest and after each response, of the number of examples needed to reach mastery (diagnosis and prescription information determined by the MAIS). Program directions for the adaptive control strategy informed students that advisement was determined according to their individual learning development in relation to mastering the concepts; in the learner control strategy, they were told that it would aid them in deciding the amount and sequence of instruction. The adaptive control condition without advisement did not provide students with information on their learning progress, nor did the learner control condition without advisement provide students with diagnostic help. Four computer-based instructional treatment programs were developed from these four conditions:

Program 1. Students had control over the amount and sequence of instruction. Advisement was given following the pretest and updated after each response (Group 1: learner control with advisement).

Program 2: Control of the amount and sequence of instruction was determined by the computer-based management program. Students were advised of their learning progress at the completion of the pretest and after each response (Group 2: adaptive control with advisement).

Program 3: Students selected the amount and sequence of instruction but without advisement on their learning needs (Group 3: learner control without advisement).

Program 4: The amount and sequence of instruction were controlled by the computer-based management program, and no advisement was given students (Group 4: adaptive control without advisement).

Facilities

The experiment was conducted in a small room in the math-science resource center at Eisenhower Senior High School. Two ADDS 780 cathode ray teletype computer terminals were used for the study. Each terminal, operating at 30 characters per second, was connected on-line by telephone to a Control Data 6400 computer at the University of Minnesota.

Procedure

As students reported for the experiment, each was assigned to a treatment program. The experimenter turned on the terminal and entered each student's treatment program number. After receiving direction on operating the terminal, students were first administered a 24-item pretest. When the pretest was finished, they received a print copy of the four concept definitions and prototype examples from the experimenter and told that they should refer to these definitions and prototype examples during the learning program. After studying the definitions and prototype examples, students 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. 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 finished the learning program, the experimenter took the definition and prototype example 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 questions. The tests and learning program required no other entries by the student. After the students had finished, the experimenter thanked them and they left the experiment room. Others were then signed on to the terminal.

Results

The data analysis consisted of a multivariate analysis with univariate tests on each dependent variable followed by mean comparison tests (Student-Newman-Keuls). Dependent variables included the correct score on the posttest, learning program time (the measured time period in which students interacted with the learning task, excluding pretest or posttest times), and number of learning program examples. The tests for homogeneity of regression of within-class and between-class linearity were nonsignificant ($p > .05$).

For the multivariate test, we used as dependent variables posttest score and time on-task. The main effect of management strategy was significant, U (1, ½, 137) = .24, $p < .001$. The test on the second main effect, advisement, was likewise significant, U (1, ½, 137) = .95, $p < .05$. The interaction test between the two independent variables was nonsignificant ($p > .05$). Following are the univariate test results on each of the dependent variables.

Posttest Correct Score

The analysis of variance on the posttest correct score (Table 1) showed a difference between the two management strategies, F (1, 135) = 24.07, $p < .001$. Students in the learner control condition (M = 16.9, 70% correct) had a posttest score 4 points lower than students in the adaptive control condition (M = 21.1; 88% correct). For the main effect of advisement, the F test was significant, F (1, 135) = 16.54, $p < .001$, with the group receiving advisement (M = 20.8; 86% correct) having scores more than 3 points higher than groups receiving no advisement (M = 17.3; 72% correct). The Student-Newman-Keuls multiple range test was used to compare posttest correct mean score differences between the four groups. At the .01 level, Group 3 (learner control without advisement) had the lowest posttest score, while the other three groups were equal. All groups achieved mastery except this one.

Criterion for mastery was set at .7 on the posttest. Group 1 (learner control with advisement), Group 2 (adaptive control with advisement), and Group 4 (adaptive control without advisement) achieved mastery at the .82, .90, and .86 levels -- 12 to 20 percent above criterion. Group 3 did not reach criterion, falling short by 13 percent (.57).

Insert Table 1 about here

Time On-Task

Average time spent on the pretest was 7.6 min; time spent on the posttest averaged 9.3 min. No significant differences appeared between groups in the pretest and posttest times ($p > .05$). The univariate test on the main effect for management strategy was significant, F (1, 135) = 89.18, $p < .001$. Students in the two learner control groups spent 6 min (M = 10.0 min) less than those in the adaptive control groups (M = 16.1 min). For the main effect of advisement, the F test was likewise significant, F (1, 135) = 8.76, $p < .05$, with the two groups receiving advisement spending 2.3 min more on task (M = 14.3 min) than those groups not receiving advisement (M = 12.0 min). A comparison of mean time differences for the four groups by the Student-Newman-Keuls multiple range test showed that Group 3 spent significantly less time ($p < .01$) than Group 1. By the same token, Group 1 spent less time ($p < .01$) than Group 2 or Group 4, both of which equalled ($p > .05$).

Insert Table 2 about here

Number of Examples

The difference in learning time is directly related to the number of examples presented in the instruction. The analysis of variance test on number of examples for the management strategy main effect was significant, F (1, 135) = 168.37, $p < .001$, with the learner control groups using a mean difference of twelve fewer instances (M = 15.2) than the adaptive groups (M = 27.0). For the main effect of advisement, F (1, 135) = 35.18, $p < .01$, the groups receiving advisement (M = 23.5) used an average mean of five more examples than the groups without it (M = 18.7). The Student-Newman-Keuls multiple range test showed that Group 3 studied the fewest number of examples ($p < .05$), Group 1 the next least amount ($p < .05$), and Groups 2 and 3 ($p > .05$) more than Groups 1 and 3 ($p > .01$). In other words, while students in the learner control without advisement condition used, on the average, only

25 percent of the possible examples, the learner control with advisement condition used 51 percent. This was 17 percent less than the two adaptive control conditions (both at 68 percent).

Discussion

Research on learner control variables has not produced instructional design variables that are generic. That is, learner control seems to be a useful management format once the correct contingency is identified, but this seems to be successful only in highly limited and well-defined occupational areas (Steinberg, 1977). Too often, contingencies associated with school-related learning, such as grades, praise, or rewards, vary in relationship to individual variables, such as sex, age, race, and home environment. This frequently results in variables and conditions too confusing for practical application or theoretical development. One purpose of this study was to introduce a variable to the basic computer-assisted learner control management strategy unlike that of previous research variables. It dealt with actual on-task learning development -- advising students of both their learning progress (diagnosis) and their individual learning need (prescription) to help them master the learning objective. Students would thus have meaningful information on which to make judgments about the amount and sequence of instruction.

As operationally defined, the variable of advisement was highly significant in providing students in the learner control condition with meaningful information with which to make appropriate decisions about acquisition of the coordinate concepts. On the posttest, students in the learner control with advisement condition (Group 1) did as well as students in the two adaptive control conditions (Groups 2 and 4, each over 80 percent correct).

The significance of this result is apparent in contrast to performance in the learner control without advisement condition (Group 3), in which students responded to only 58 percent of the posttest items correctly (identical to the pretest). This outcome of the learner control without advisement condition is consistent with previous research (Tennyson, in press), which has shown that even with a strong contingency such as a grade, students learn little from instruction; research has furthermore shown that no matter what level of on-task attainment is reached, all students leave instruction at approximately the same time (see Tennyson & Rothen, 1979).

The dependent variable of time is important to consider in the study of learner control management strategies because students in a learner control condition consistently leave instruction before mastering the objective (Tennyson, Tennyson, & Rothen, in press). In contrast to this basic finding, students in the learner control group which received advisement stayed on-task long enough to obtain mastery. In fact, they were on-task approximately 39 percent longer than the students in the conventional learner control condition. It was our thesis that if students in a learner control strategy were given advisement in the form of adaptive diagnostics and prescriptions, they would master the objective in less time and use less instruction than in a program-controlled adaptive system. The assumption was that the cognitive strategy that students used in learning would further refine the adaptive information. The findings support this notion. The two conditions using the adaptive information (adaptive control and learner-adaptive control) had identical posttest-score means, but the learner control with advisement condition showed significant decreases in on-task time (22 percent less) and amount of instruction (25 percent less).

In conclusion, a learner control condition can be a valuable instructional management system, especially for computer-based instruction, if students receive sufficient information about their learning development -- information that continuously shows them what progress they have made toward mastery of the objective and provides meaningful advice on appropriate stimuli necessary to obtain it.

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Table I

Mean and Standard Deviations for Posttest Correct Scores

Advisement	Management Strategy	
	Learner Control	Adaptive Control
With	Group 1:	Group 2:
M	19.9	21.6
SD	3.3	3.2
Without	Group 3:	Group 4:
M	13.9	20.6
SD	3.3	3.7

Note: Maximum posttest score = 24

Table II

Mean and Standard Deviations

for Time On-Task and Number of Examples

Advisement	Management Strategy			
	Learner Control		Adaptive Control	
	Time	Number	Time	Number
With	Group 1:		Group 2:	
_M_	12.5	20.2	16.0	26.7
_SD_	5.5	9.0	4.4	5.6
Without	Group 3:		Group 4:	
_M_	7.7	10.1	16.2	27.3
_SD_	6.7	8.7	3.0	4.2