DOCUMENT RESUME

ED 156 458 SE 024 373

AUTHOR Gerlach, Vernon S.; Schmid, Richard F.
TITLE The Efficiency of Algorithmized Instruction.
INSTITUTION Arizona State Univ., Tempe.
SPONS AGENCY Air Force Office of Scientific Research, Arlington, Va.
PUB DATE Mar 78
GRANT AFOSR-76-2900
NOTE 5p.; Paper presented at the annual meeting of the American Educational Research Association (Toronto, Canada, March 27-31, 1978)

EDRS PRICE MF-$0.83 HC-$1.67 Plus Postage.
DESCRIPTORS *Algorithms; Calculation; *Educational Research; Flow Charts; Higher Education; *Instruction; Investigations; Mathematics Education; *Problem Solving; *Teaching Methods; Undergraduate Students
IDENTIFIERS *Computation

ABSTRACT

This experiment was conducted to determine the efficiency of three forms of an algorithm of known effectiveness and the effects of its availability following initial instruction. The dependent variable was time to solve computational problems requiring rule application. The algorithm was presented in three forms: prose, flowchart, and gradual withdrawal of flowchart. The algorithm was either available during instruction and testing or during instruction only. Results indicate that, over time, algorithmized instruction significantly decreased time to solve problems, even after a week's delay, and that recourse to the algorithm reduced instructional time and results in faster learner performance. (Author/MN)

ED156458

The Efficiency of Algorithmized Instruction

VERNON S. GERLACH and RICHARD F. SCHMID
ARIZONA STATE UNIVERSITY

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The research on which this article was based was supported in part by the United States Air Force Office of Scientific Research, Grant No. 76-2900, awarded to Arizona State University; Vernon S. Gerlach is the Principal Investigator.

VERNON S. GERLACH
EDB-146
ARIZONA STATE UNIVERSITY
TEMPE, AZ 85281

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(a) Objective

To assess the efficiency, in terms of both instructional and posttest performance times, of an instructional algorithm in three representational forms (prose; flowchart; gradual withdrawal of flowchart), in two availability modes (with recourse to algorithm during practice and posttest; without recourse).

(b) Perspective

An algorithm is "a procedure which will produce the correct result when applied to any problem of a given class of problems" (Gerlach, Reiser, & Brecke; 1976). In recent years a number of works advocating the algorithmization of instruction have appeared. Although some research has demonstrated that instructional algorithms can produce desired outcomes (Landa, 1973), it still remains unclear as to exactly when an algorithm should be used and in what form algorithms should be presented. Landa (1976) has stated that, at present, the only way to determine whether a given unit of subject matter is amenable to algorithmization is to try to construct the algorithm and, if successful, to test the algorithm with appropriate learners. The present study is an effort to go beyond this kind of primitive empiricism by providing data which can be used in beginning to formulate general principles concerning algorithmization of instruction. Three algorithms were used whose effectiveness was known; the efficiency of the algorithms in terms of time needed for instruction as well as speed of performance on both immediate and delayed posttests was determined. In addition, we observed the degree to which subjects became dependent on the actual presence of the algorithm during and after instruction.

(c) Method

Design. Three factors, Tax Law Availability, Instructional Representation, and Test Interval were combined factorially to form six treatment groups. Test Interval was varied as a within-subject factor. The design was thus a 2 Availability (with tax law vs. without) X 3 Representation (prose vs. flowchart vs. faded flowchart) X 2 Test (immediate vs. delay). Analyses of variance, with repeated measures on Test Interval, were employed.

Materials. The instructional task was adapted from Horabin's Algorithms (1974). The task consisted on generating the solution to tax problems involving the purchase and sale of shares of stock. The authors created two sample problems for each of six possible solutions, from which two sets of problems were created. Instruction on how to apply the tax law took one of three representational forms: the prose condition received a verbal description of the law, which followed an if/then format; the flowchart condition received the same information in a flowchart form, such that each decision (discriminator) was binary, leading to another discriminator, until the terminal solution box (operator) was reached; the faded flowchart was exactly the same as the flowchart treatment, except that for each problem completed, one of the discriminators necessary for the solution of subsequent problems was deleted. The deleted information was made available only if the subject was unable to recall it. Corrective feedback was supplied in separate booklets.

The questionnaire following the treatment asked about the learner's strategies and reactions to the instruction. The posttest contained six additional randomly ordered problems of the same type, without feedback. The delayed posttest and the immediate posttest were identical, except for the order of the problems.

Procedure. The experimental sequence consisted of (a) an orientation, (b) a practice session, (c) an immediate posttest, (d) a questionnaire, (e) a one-week delay posttest, and (f) a questionnaire. In addition to completing six practice and six posttest problems, subjects recorded the time in spaces provided at the start and finish of each problem. Following the introduction read aloud by the experimenter, subjects completed all phases at their own pace. During both posttests, only half the subjects from each condition were supplied the tax law for solving the problems.

(d) Data Source

Data consisted of time on practice and time on posttest for 77 undergraduate volunteers from Arizona State University. Eleven subjects were dropped from the experiment for failure to follow procedures, leaving 11 per factorial cell. Subjects were run in groups during normal classroom sessions. Materials were prepared beforehand and shuffled, so that assignment to treatments were completely randomized.

(e) Results and Conclusions

Time data was generated by computing the mean number of seconds spent per problem during instruction and during testing. Omitted problems were not included in the estimates.

Analyses of variance (3 Representation X 2 Availability) were conducted on the practice and posttest sections. A repeated measures anova using the delayed test data was then performed. The repeated measures anova was conducted twice: first, using groups as represented by the with/without distinction on the immediate posttest, and then using groups separated according to the Availability factor on the delayed test.

Time values obtained during the practice section were significantly different for Representation, $F(2,60) = 8.44$, $p < .001$, with Scheffe' tests ordering the means, flowchart < prose = faded flowchart. However, immediate posttest times did not differ significantly, either for the three algorithm groups or for the availability of the tax law. Subjects who had recourse to the law did not solve the problems more quickly than did subjects without recourse to the law.

The repeated measures anova on the original groups yielded significance for the Representation factor, $F(2,54) - 3.16$, $p < .04$, and for the Test main effect, $F(1,54) = 15.28$, $p < .001$. Scheffe' tests indicated that prose and flowchart groups spent significantly less time than the faded flowchart group. Less time was spent on the delayed test than the immediate posttest. When subjects were regrouped according to Availability for the delayed test, Representation was significant, $F(2.54) = 3.83$, $p < .02$, the Test factor was significant,

$F(1.54 = 11.98$, $p < .001$, and the Representation X Availability Interaction reached significance, $F(2,54) = 6.16$, $p < .004$. Scheffe' tests again showed that the prose and flowchart groups spent less time than the faded flowchart groups. Subjects also spent significantly less time on the delayed test. Individual comparisons on the interaction demonstrated that only the faded flowchart groups spent significantly more time when not supplied with the tax law. No other differences were found.

These results suggest that the type of task employed in the present experiment can be efficiently taught through algorithms. Subjects were able to solve complex tax problems involving seven discriminators and six operators at the 75% level of accuracy after only 12-15 minutes of instruction. The algorithms required the learner to make a maximum of three unambiguous binary decisions which always lead to the correct result. Surprisingly, subjects spent significantly less time solving problems after a one week delay, with a decrement of only 15% when two of the three algorithms were withheld.

Although one study cannot demonstrate conclusively which algorithmic form of instruction is most efficient these data do provide some tentative answers to this crucial problem. The prose and flowchart treatments completed the problems consistently faster than the faded flowchart group, despite the fact that the faded flowchart group enjoyed significantly more practice time. However, overall efficiency was greater for the flowchart group than the faded flowchart condition. The efficiency of the faded flowchart continued to diminish over the one week delay. The similarity between the prose and flowchart conditions was that they provided the subject with an easy, systematic means of solving relatively complex tasks without requiring piecemeal mastery of the procedure. Subjects utilized the algorithm as a problem solving device, and simultaneously learned the procedure, resulting in high efficiency. The faded flowchart was similar to traditional classroom instruction in that subjects were taught one section of the algorithm, asked to master it and then go on to the next section. Such a system denies the step-by-step, logical characteristics of algorithmic instruction, and ultimately proves less effective and less efficient. The Availability data also suggested that when algorithmic information is faded out during instruction, subjects performed significantly less well over time than when the algorithm is dealt with in a more unitary, organized fashion.

(f) Educational importance of the study

The study demonstrates that, when dealing with instruction involving rule application to the solving of computational problems, algorithmized instruction yields a significant time savings. Of particular importance for instructional developers is the indication that, rather than trying to teach the learner to internalize an algorithm, the learner should have constant recourse to it; both speed and accuracy are increased under this condition.