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EFFECTS OF MATHEMATICAL ABILITY, PRETRAINING, AND INTEREST ON SELF-DIRECTION IN PROGRAMED INSTRUCTION.

BY- CAMPBELL, VINCENT N. AND OTHERS
AMERICAN INST. FOR RESEARCH IN BEHAVIORAL SCIENCES

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THE HYPOTHESIS OF THIS EXPERIMENT WAS THAT SELF-DIRECTION WOULD BE MORE EFFECTIVE WITH STUDENTS OF HIGH RATHER THAN LOW ABILITY AND INTEREST PROVIDED THEY HAD HAD COACHED PRACTICE IN SELF-DIRECTED USE OF PROGRAMED MATERIALS. SUBJECTS WERE 34 GRADE 9 ALGEBRA STUDENTS. THEY COMPLETED PRE-EXPERIMENTAL ABILITY TESTS AND INTEREST QUESTIONNAIRES. HALF WERE PAID FOR PRE-TRAINING SESSIONS DURING WHICH THEY WERE EXPOSED TO LINEAR (L) AND SELF-DIRECTED (SD) PROGRAMS ON PERMUTATIONS. KEY FEATURE OF THE SD PROGRAM WAS COMPLETE FREEDOM AS TO EXTENT, SEQUENCE, AND METHOD OF STUDY. THEN THE VARIABLES PROGRAM TYPE AND PRE-TRAINING WERE TESTED WITH PROGRAMS ON SET THEORY. ANALYSIS OF COVARIANCE ON GAIN SCORES AND POST-TEST QUESTIONNAIRES SUPPORTED THE HYPOTHESIS AND SUGGESTED THAT SD TECHNIQUES ARE MORE POPULAR WITH HIGH ABILITY STUDENTS AND ARE MORE EFFECTIVE AFTER PRACTICE AND DISCUSSION OF SELF-DIRECTION. THE SD GROUP SHOWED MARKED SUPERIORITY ON THE PRE-TRAINING TOPIC ITSELF. (LH)

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AMERICAN INSTITUTE FOR RESEARCH/PALO ALTO

AMERICAN INSTITUTE FOR RESEARCH

mailing address: Station A, P.O. Box 11487, Palo Alto, Calif.
Telephone 321-2130 (Area Code 415)
office location: 1791 Arastradero Road, Palo Alto, California

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EFFECTS OF MATHEMATICAL ABILITY, PRETRAINING, AND INTEREST ON SELF-DIRECTION IN PROGRAMED INSTRUCTION

In a previous study by the authors (Bivens, Campbell, and Terry, 1963) it was found that mathematical instructional programs which required students to organize and evaluate their own learning were no more effective in enhancing learning than more conventional linear programs. However, these results were obtained using students in the lower half of the mathematical achievement distribution and it was hypothesized that Ss of higher ability and/or achievement might be able to make more effective use of the self-direction characteristics of the programs used. Also, our observations of individual Ss working with the self-directing programs suggested that some degree of pretraining in the use of self-directing materials might further enhance the effectiveness of such procedures. Finally, we also felt that a student's intrinsic interest in the programed topics might bear some critical relationship to effective use of self-directing programs. In brief, it was hypothesized that self-direction might work better with more able, interested students who have had coached practice in self-directed use of programed materials.

Method

Subjects

One ninth-grade summer school algebra class served as Ss in this experiment. The class comprised a total of 34 Ss, 32 of which were above the 50th percentile of mathematical ability (national norms).

Material

Program Formats. Two learning programs were used, one program on permutations and combinations (Campbell & Terry, 1962) and the other on elementary set theory (Campbell, Terry, & Shearer, 1962). Each program was prepared in a linear form and a self-directed form. The linear program form differed from the typical "Skinnerian" program in that a large step-size was used and fewer responses were called for. This type of linear program was considered more relevant for these materials since

the basic orientation of the program was toward concept development as opposed to verbal response. Both linear and self-directed forms of the program consisted of basic text, examples and explanations, and self-test items all in booklet format, although these components were assembled differently in the self-directed format than in the linear format, as described in more detail later. Correct answers to self-test items, and to the occasional questions in the other materials, always appeared on the following page.

In the linear form, all of these components were assembled in a single orderly step-by-step sequence and students were required to proceed through the program page-by-page, answering all questions and reading all of the material. The linear permutations program was divided into eight chapters, the last two chapters containing only review items. Each chapter covered a particular concept, such as "permutations as one-to-one matchings," "partial permutations," "combinations," etc. Basic information, examples, explanations, and self-test items were arranged in what was considered to be the most logical and orderly sequence of presentation. The linear sets program was similarly constructed except that there were only seven chapters, the last two of which were review.

In the self-directed form of the two programs, materials were assembled differently and students instructed to proceed differently than with the linear form. As to assembly of materials, the three components (text, examples and explanations, and self-test items) were color coded and kept physically separate, but were clearly identified as to their nature and were cross-indexed to each other. In the self-directed permutations program, the text was divided into two booklets, one covering permutations, the other covering partial permutations and combinations. Examples and explanations were in 14 separate booklets, each booklet covering a particular subtopic or idea. Self-test questions were divided into 21 separate booklets. Each page of the text was indexed to an example and explanation booklet and to a self-test booklet by a capital letter appearing on all three components. The self-directed sets program was similarly constructed except that there was only one text booklet and 15 booklets of both examples and explanations, and self-test questions.

Instructions for the self-directed condition told Ss to go through the program in any manner they wished. Overt responses to self-test items were not required nor were Ss required to read all the material. Ss had complete freedom as to extent, sequence, or method of study.

In addition to the program materials, both the linear and self-directed groups had an outline of key concepts which was indexed to the other learning materials. Under self-directed conditions, Ss were permitted to refer to the outline throughout the program but Ss under linear conditions used the outline only for review after completing the program.

Interest Questionnaire. A questionnaire designed to measure intrinsic interest or motivation toward study of set theory was developed. Brief, 10-page programs for each of three topics (Set theory, Circulation of the Blood, and Far Eastern Geography) were prepared and mailed to Ss along with a form on which the Ss were to rate each of the three topics on a seven point scale ranging from "like very much" to "dislike very much." They were to read the three "sample" programs and then rate each topic as to how much they would like to study it. The purpose was not to permit each S to choose his own topic for the experiment, but to obtain a relative index of interest in the set theory lesson actually to be used in the experiment, so that interest could be correlated with criterion performance. At the time these questionnaires were administered, Ss were unaware that they would be studying set theory during the forthcoming summer session, either as a regular class lesson or in the planned experiment.

Post-Program Questionnaire. A questionnaire was developed in order to assess Ss' preference for linear and self-directed formats and to determine how Ss under the two conditions went about the learning task. Questionnaires for self-directed and linear Ss appear in the appendix.

Pretraining

Nineteen paid volunteers from the class were given approximately 4 hours of pretraining (1 hour per day immediately following their algebra class) in either self-directed (10 Ss) or linear (9 Ss) study, using the permutations program. For self-directing Ss, the major portion of the first pretraining session was devoted to a group discussion intended

to cause each S to think about self-direction in his own schoolwork and to relate this to the material at hand. During the remainder of the pretraining sessions, each self-directing S studied the program materials in whatever manner he chose. E interrupted each session once or twice in order to elicit discussion of study tactics.

In the linear pretraining sessions, E emphasized the step-by-step study procedure, reminding the group to read all the material carefully and exactly in the manner prescribed since they were not permitted to retrace. Study sessions were occasionally interrupted and student opinion of the form and content of the lesson was solicited.

The last day of pretraining was concluded by giving all Ss in both groups a criterion test over permutations and combinations. Self-directing Ss were briefly urged to apply any new study skills or perspectives to the study of sets during the week to come.

Training

Self-directing and linear sets programs were administered the week following pretraining. Ss pretrained on linear study were given linear programs and Ss pretrained on self-directed procedures were given self-directing programs. Ss not participating in the pretraining sessions were divided into linear and self-directing groups so that a total of four groups were used during the training phase: pretrained self-directing, pretrained linear, non-pretrained self-directing, and non-pretrained linear. The number of Ss in each group was 10, 8, 7, and 6 respectively. All students were given a pretest on sets before they began studying.

Self-directed Ss were permitted to take an immediate posttest at any time they felt ready. Linear Ss could take this test only after they had completed five of the seven chapters in the linear program (the last two chapters were review chapters). The immediate posttest was a parallel form of the pretest.

After five 40-minute periods of study, all Ss were given the post-program questionnaire. Immediately after completing the questionnaire, all Ss were given a final criterion test which was the same as the pretest.

Complete copies of the criterion tests for both lessons (sets; permutations) appear in the appendix of the report previously cited (Bivens et al., op. cit.)

Results

Pretraining Test Scores

An analysis of covariance was performed on the test results of the permutations and combinations lesson that was used for the pretraining sessions. Gain scores were not available since no pretest was administered. Differential Aptitude Test scores (DAT - Numerical Ability) and School and College Ability Test scores (SCAT - Quantitative subtest) were used as predictor variables in this analysis (it was necessary to use both DAT's and SCAT's because some Ss had only taken the DAT while others had taken only the SCAT). The correlations of the DAT and SCAT percentiles with permutations and combinations test scores were .29 for the self-directed group and .56 for the linear group. Adjusted criterion test means for self-directed and linear groups were 42.0 and 33.2 respectively and were significantly different at the .005 level.

Pretest - Immediate Test Gains (Gain Score 1)

Mean times spent in study prior to the first posttest, and corresponding gain scores for the set theory lesson (adjusted by mean class grades on four previous mathematics tests) for the four groups are shown in Table 1. Most Ss took the immediate posttest during either the 4th or 5th study period although one S in the self-directing group and four Ss in the linear group took the test as early as the 3rd study period; i.e., 4 Ss in the linear group completed the required 5 out of 7 chapters by the end of the 3rd study period. An analysis of covariance was performed on Gain Score 1 and yielded a significant main effect of study method ($p < .025$) and a significant interaction ($p < .01$). The main effect of pretraining was not significant. A test of the difference in adjusted Gain Score 1 for the pretrained self-directed group (19.9) versus the other three groups combined (14.0) was significant at the .02 level. However, the difference between the pretrained and non-pretrained self-directed groups alone was not significant ($t = 1.41$, $p < .20$).

Table 1

Adjusted Mean Gain Scores (Sets),

Class Grades, and Study Times, for Training

	Pretrained		Non-pretrained	
	Self-directed	Linear	Self-directed	Linear
N	10	8	7	6
Mean Class Grade	75.9	66.1	66.8	64.4
Study Time to First Posttest (min.)	138	135	157	138
Adjusted Gain Score 1 (Pretest to First Posttest)	19.9	10.4	16.1	16.4
Adjusted Gain Score 2 (Pretest to Final Posttest)	19.5	17.0	14.5	18.9

Table 2

Correlations of Sets Gain Scores with

Ability and Interest in Set Theory

(Pretrained and non-pretrained groups combined)

	Class Grade	DAT or SCAT Score	Interest in Set Theory
Gain Score 1 (Pretest to First Posttest)			
Self-Directed	.09	.22	.31
Linear	.34	-.08	-.04
Gain Score 2 (Pretest to Final Posttest)			
Self-Directed	.35	.20	.47 *
Linear	.44	.11	-.17

* Difference significant at .05 level

Pretest - Final Test Gains (Gain Score 2)

Analysis of covariance of Gain Score 2, using mean grades as a predictor variable, revealed no significant main effects of pretraining or teaching method. The interaction was significant at the .10 level. Mean class grades were used as the predictor variable in these analyses because they correlated higher with gain scores than did the available ability measures (see Table 2 for correlations of mathematics grades, ability measures, and interest in set theory with gain scores). A test of the difference in adjusted Gain Score 2 between the two self-directed groups (with and without pretraining) yielded an F significant at the .10 level, favoring the pretrained group.

Post-Program Questionnaire

Questionnaire items and responses are summarized in the appendix. Responses to the item asking Ss how much they enjoyed studying sets followed the opposite pattern from the study with low-ability Ss (Bivens, et. al., op. cit.) in that the self-directing Ss rated their learning method higher than linear Ss, although the difference was not significant. Mean ratings for this item were 4.9 for Ss using the linear programs and 5.6 for Ss using the self-directed program (a rating of 7 indicated that Ss liked the sets lesson very much; a rating of 4 was neutral).

Most Ss in both self-directed and linear conditions indicated a preference for more self-test questions and worked out examples. Those Ss who received pretraining were asked if the pretraining sessions helped them to organize or study the set theory material. In both linear and self-directed pretrained groups, all Ss reported that these sessions were of some help. However, responses to questionnaire items asking self-directed Ss if they had any difficulty in organizing the self-directing materials were essentially the same for both pretrained and non-pretrained Ss. Ss reported little or no difficulty in organizing the materials, even those Ss receiving no pretraining.

Item 5 of the questionnaire given to the self-directing groups asked them to describe the procedure they used in studying the self-directing program. Those Ss who indicated that they worked through the program by first reading all of the text, then all of the examples and explana-

tions, then all of the self-test questions had significantly lower mean mathematics grades ($p < .05$) and lower final gain scores (adjusted by mathematics grades; $p < .10$) than Ss following any other procedures. In effect, these Ss were not directing their own study but were going through the program in a rather inefficient linear manner, apparently a danger of unguided self-direction.

Discussion

Compared with the results of the study with low-ability Ss, the results of this study suggest that these techniques are more popular with students of higher ability/achievement and are more effective after such Ss have practiced and discussed their use of self-direction for a few days.

The most striking result of this experiment was the marked superiority of the self-directing group on the pretraining topic itself. After adjusting for math grade difference between groups, the difference of 8.8 points represents over 17% of the test range. For these same two groups a comparable adjusted difference of 9.5 points (29% of the test range -- $p < .05$) was obtained on the first sets posttest after approximately equivalent study times. This suggests that learning skills acquired by the self-directing group during pretraining were not forgotten as soon as coaching ceased but were retained and used during training. On the final sets posttest the difference diminished to 2.5 points. It is unlikely that self-direction skills diminished much between the two posttests. A more likely explanation is that all groups were approaching a common asymptote of amount learned when the final posttest was given.

The superiority of the pretrained self-directing group on Gain Score 1 is smaller when the two groups given no pretraining are considered (see Table 1). Their adjusted means fall midway between those of the pretrained group. Why the unpretrained linear group should exceed the pretrained linear group is uncertain since their means on math grade, ability, and interest in set theory do not differ. Unless the result is due to sampling error, a novelty effect may possibly have favored the untrained group in that the sets materials were quite

similar in form to the permutations-combinations materials. If so, the superiority maintained by the pretrained self-directing Ss is the more noteworthy.

The correlation between gain scores and interest in set theory was, as hypothesized, positive for the combined self-directing groups. In contrast the correlations were approximately zero (-.04, -.17) for the combined linear groups, although the difference between correlations for the self-directed and linear groups was significant ($p < .05$, one-tailed) only for Gain Score 2. As a whole, these correlations support the idea that interest in the topic studied is more critical to successful learning when students direct their own study than when a linear program is given according to a fixed procedure.

The correlations between ability and amount learned appear to underestimate the relationship because of the restricted ability range. Pooling the data from this experiment with that of the study with low-ability Ss, the correlations of ability and performance considerably increased. For the sets program, the correlation of ability and performance was .75 for the self-directing Ss and .41 for linear Ss. On the permutations and combinations data, these correlations were .49 and .26 respectively. This is in contrast to results obtained by Gruber and Weitman (1962) in which ability bore no appreciable relation to amount learned in studies of longer-term, more unstructured self-direction by college students.

The present study revealed a stronger liking for self-directed than for linear study of the sets lesson, the opposite of the findings of the previous study. However, the smaller sample of this experiment prevented the differences from being statistically significant, even though the absolute difference was as large. The liking for both methods was higher in this study than in the previous one. This may be attributable to the different setting (summer school vs. spring of the regular year) or to the different population of students samples. It appears reasonable that capable, interested students will like to study and will achieve more by it as compared to low-ability students.

Answers to other items of the questionnaire indicated that these high-ability self-directing Ss experienced very little confusion or

doubt, regardless of whether they were directing themselves successfully or unsuccessfully.

The differences between Ss who studied the self-directing programs in different ways are rather interesting. Ss who read all of each type of material (text, examples and explanations, and self-test questions) before going on to the next were apparently reading the program in the sequence that the packages of materials were placed when they were handed out. That is, they made little or no effort to derive a logical study procedure from the available materials. This lack of organization may be due to a motivational rather than an ability factor since the mean DAT and SCAT scores for the Ss using the self-directing programs in this linear fashion is actually higher (although not significantly so) than for Ss taking more advantage of the self-directing features of the program (84.1 vs. 77.1), whereas their class grades are lower ($p < .05$).

In conclusion, it appears that a week's practice emphasizing critical examination by the student of his own step-by-step study decisions made a noticeable difference in the effectiveness of self-directed use of mathematics programs. Interest in the topic appeared also to contribute at least a small amount to the effectiveness of self-directed, but not linear, programed instruction.

References

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Gruber, H. E. & Weitman, M. Self-directed study: experiments in higher education. University of Colorado Behavior Research Laboratory Report No. 19, April, 1962.

APPENDIX

Frequency of Alternative Answers to each Item of the Post-Program Questionnaire

Response Frequency for Each Questionnaire Item
(Pretrained and unpretrained conditions pooled)

Items answered by both self-directed (SD) and Linear Ss

SD	Linear		
		1.	How much did you enjoy studying sets?
4	1		liked it very much
6	5		liked it
4	2		liked it a little
2	5		neutral
1	0		disliked it a little
0	1		disliked it
0	0		disliked it very much
		2.	Would you be interested in learning more about sets?
1	0		definitely yes
8	5		yes, I think so
5	6		could take it or leave it
3	2		no, I don't think so
0	1		definitely not

Items answered by Linear Ss only

	3.	How often did you wish you could stop and get more explanation or examples of a certain idea, instead of going straight on through the chapter?
0		many times a day
1		a few times a day
7		once or twice a day
4		less than once a day
2		never
	4.	What changes in the lesson would you suggest before we give it to other students? (Check as many answers as you want)
4		give the students more choice as to <u>how</u> they study

8	more questions to answer
2	fewer questions to answer
10	more worked out examples
0	fewer worked out examples
8	more general explanation in the text
0	less general explanation in the text
2	more help from the teacher
0	more work space on chair or desk

Items answered only by Self-directed Ss

3. Listed below are the four types of materials in the lesson. Place a 1 in the blank beside the material from which you learned the most. Place a 2 beside the one from which you learned the 2nd most. Place a 3 beside the one from which you learned the 3rd most. Place a 4 beside the material from which you learned the least.

Rank				
1st	2nd	3rd	4th	
0	2	3	12	Outline
7	4	5	1	Text (green covers)
7	4	2	4	Examples and Explanations (pink covers)
3	7	7	0	Self-test items (yellow covers)

4. Listed below are the four types of materials in the lesson. Place a 1 in the blank beside the material you spent the most time on. Place a 2 beside the one you spent next most time on. Place a 3 beside the one you spent third most time on. Place a 4 in the blank next to the material you spent the least time on.

Rank				
1st	2nd	3rd	4th	
0	1	4	11	Outline
3	4	8	1	Text (green covers)
8	2	2	4	Examples and Explanations (pink covers)
5	9	2	0	Self-test items (yellow covers)

5. Which procedure did you use in sutdying the lesson?

8 read all of one type of materials (that is, all of the same color) before going on to a different type

2 read <u>all types</u> of materials on one idea (that is, <u>all</u> materials falling under a certain capital letter) before going on to the next idea or letter

1 followed no particular procedure

6 followed a procedure different than those described above.

6. On the average, how often did you use the <u>numbers as an index</u> to other materials?

3 many times a day
3 a few times a day*
3 once or twice a day
6 less than once a day
2 never

7. If you couldn't understand something, did you stop and look for other materials covering the same idea?

0 no
0 not usually
3 sometimes
10 most of the time
4 always

8. Did you have difficulty deciding what to do next?

15 no
2 only at first
0 sometimes
0 usually
0 always

9. How much did you improve at organizing your own study between the first day on this lesson and the last day?

5 none
4 just a little
3 some
5 a great deal

10. How did you decide when to take the test for the first time? (Check one or more answers)

1 asked other students who had taken it how hard it was

11 judged by whether I could answer self-test questions (in yellow booklets)

4 studied until I could answer the sample questions on the outline

8 studied until I felt I knew all the main ideas

2 I ran out of time and had to take the test

11. Did you change your method of study after taking the test the first time?

3 yes.

11 no

2 didn't study any more after the first test

12. What changes in the lesson would you suggest before we give it to other students? (Check as many answers as you want.)

3 put all the materials in a certain required order instead of having the students choose on their own

8 more self-test questions

6 more explanations and examples

3 more help from the teacher

3 not so many different study materials

2 more work space on chair or desk