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ABSTRACT

Presented are the procedures, results, and conclusions of a study designed to compare the effectiveness of programed instructional materials with that of conventional materials in university physical science laboratory classes. The subjects were students enrolled in two similar freshmen-level physical science general education courses who were non-randomly assigned to the experimental and control groups. The control group students used the conventional manual for the laboratory experiments while the experimental group students used the programed instructional materials for four out of seven investigations. The subjects were pretested on the Scholastic Aptitude Test and an investigator-constructed physical science test. Final measures included scores on the physical science test, scores on a lab-test, laboratory grades and course grades. Attitudinal measures were also administered to the experimental group students. Major findings were: (1) students can achieve equally well on physical science subject matter written evaluative measures whether they use programed laboratory materials on conventional materials, (2) students can achieve equally well in laboratory performance with either one of the materials, and (3) both students and instructors preferred programed to conventional material. (LC)

AN EXPERIMENTAL STUDY OF THE USE OF PROGRAMMED INSTRUCTION IN A UNIVERSITY PHYSICAL SCIENCE LABORATORY

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by

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The purpose of this study was (1) to design, develop, and evaluate programmed instructional materials which could be used in university physical science laboratory classes, and (2) to compare the use of these materials with the use of conventional materials.[1] This report emphasizes the comparisons in the use of programmed materials; it does not detail the preparation of the programs.

Procedures

This research was conducted as a field study, using actual physical science laboratory classes, classrooms, and regular instructors. There were no contrived or artificial learning situations. No special schedules or facilities were utilized other than the programmed materials designed for use in this study.

Subjects and treatment

The subjects were all of the students enrolled in two similar freshman-level physical science general education courses at Eastern Michigan University in the fall semester, 1966. In the lecture portions of the two courses, students covered similar subject matter. All students in the two courses were assigned the same series of laboratory investigations. The titles and sequence of the investigations are given in Table 1.

TABLE 1

TREATMENT ARRANGEMENTS FOR LABORATORY INVESTIGATIONS

Investigation Number and Name	C Group Treatment	E Group Treatment	Labtest Item Number
1. Measurement and Archimedes' Principle	Conventional	Conventional	5
2. Simple Pendulum	Conventional	Programmed	2
3. Linear Air Track	Conventional	Conventional	1
4. Mechanical Equivalent of Heat	Conventional	Programmed	4
5. Magnets	Conventional	Conventional	-
6. Light Spectra	Conventional	Programmed	3
7. Radioactivity	Conventional	Programmed	-

There was a total of twelve laboratory sections. Six sections were assigned to an Experimental Group (or E Group, N = 105); the remaining six sections were designated as the Control Group (or C Group, N = 109). Scheduling difficulties precluded random assignment of students to sections; laboratory sections were assigned to E or C Group on the basis of course, instructor, time-of-day, and time-of-week.

During the semester, all Control Group students followed the narrative-form loose-leaf laboratory manual which had been used for several years in the physical science courses. For each investigation, this "conventional" manual contained introductory textual material, directions for laboratory procedures, blank data tables, and questions for students to answer in the subsequent written report. In addition, the laboratory instructor lectured for several minutes at the beginning of each laboratory period to explain further the principles and procedures involved in the investigation.

All Experimental Group students used the conventional laboratory manual for three investigations. See Table 1. For the other four investigations, they used programmed instructional materials which were prepared specifically for this study as described briefly below. For each investigation, the experimental materials contained programmed introductory information, directions for laboratory procedures, blank data tables, and questions to be answered in the subsequent report. Students were expected to work through programmed portions before entering the laboratory for an investigation; instructors did not lecture in the laboratory.

Programmed instruction

The programs prepared by this investigator for this study served an information-presenting function; instructional material which was programmed was that needed in preparation for data collection. Laboratory procedures, per se, were not programmed.

The programs prepared were written to behavioral objectives of the four investigations, using a linear paradigm with a combination of constructed and discrimination responses. During development, programs were tried out with individuals, edited by subject matter and programming consultants, field tested, and revised as seemed to be necessary to effect learning.

Evaluation measures

Initial measures included scores on the Scholastic Aptitude Test (SAT) and a pretest, The Physical Science Test. The twenty-four-item multiple-choice Physical Science Test had been previously prepared and validated by the instructor in charge of the physical science courses at the University.[2]

Final measures included: scores on the Physical Science Test as a posttest, total scores on a laboratory performance examination (Labtest), scores on individual items of the Labtest, laboratory grades, and course grades.

The Labtest, developed for this study, consisted of five items, each of which sampled the attainment of objectives of one laboratory investigation. Using apparatus which was previously set up, students were required to make specified measurements and calculations within certain time limits. The topics of Labtest items are indicated in Table 1.

Laboratory grades were prepared by laboratory instructors. Course grades were determined by the instructor in charge of the physical science courses, with the aid of a special computer program.

Two addititudinal measures were used at the close of the semester. Experimental Group students responded to a questionnaire concerning their opinions toward programmed and conventional materials. In tape-recorded interviews, laboratory instructors commented on their observations of the use of the two instructional methods and student behavior in the Experimental and Control Groups.

Hypotheses

The major hypothesis of this study was:

> There are no significant differences between university physical science students who use programmed materials for laboratory instruction (Experimental Group, or E Group) and those who use conventional materials for laboratory instruction (Control Group, or C Group).

The major hypothesis was tested by separating it into several null hypotheses which are not detailed herein. The sub-hypotheses were based on the subgroups: the two physical science courses, sex, and ability levels (determined from SAT scores). Differences between the means of subgroups and total groups were tested on each of the initial and final measures.

Uniqueness of This Study

The general design of this study is similar to that of many other educational studies: comparisons are made between students in an experimental group and students in a control group. This study differs in several respects from previous studies involving programmed instruction in school science laboratories: (1) the content of the instructional materials used was not experimental--the subject matter and laboratory investigations had been in use for several years; (2) treatment groups were handled by regular laboratory instructors in a routine manner; (3) no special facilities or apparatus were used for the study; (4) laboratory procedures, *per se*, were not programmed; (5) in addition to pencil-and-paper final evaluative measures, a laboratory performance examination was used.

Statistical Analyses and Results

Computer programs for the analysis of variance and t-ratios were used to compare treatment groups (i.e., E. Group with C Group) and to compare subgroups. The significance of the differences between the means of the various groups and subgroups on all measures was tested. Results of comparisons between the two major treatment groups are shown in Table 2.

No significant differences were found between E and C Groups on initial measures. Hence, the groups can be considered to be samples derived from a population of students with similar abilities (as measures by the SAT), and similar previous knowledge of physical science (as measured by the Physical Science Test).

When the various comparisons were made on the final measures, the E Group had higher mean scores approximately as many times as did the C Group. However, none of the differences were significant. It was apparent that the two instructional methods compared had about the same posttreatment effect on each of the two groups, including the effect on measures directly related to laboratory work: The Labtest, Labtest items, and laboratory grade.

TABLE 2

ANALYSIS OF VARIANCE AND t-RATIOS FOR COMPARISONS BETWEEN EXPERIMENTAL AND CONTROL GROUPS

Variable and Group[a]	Analysis of Variance				t-Ratio[d]
	Mean[b]	SD[b]	df	F[c]	
SAT scores					
E	50.04	30.80	203	.94	.97
C	45.95	29.29			
Pretest					
E	9.14	2.70	204	.07	.26
C	9.04	2.91			
Posttest					
E	12.69	3.60	213	1.17	1.08
C	12.13	3.92			
Labtest total					
E	55.37	19.49	209	1.38	-1.17
C	58.62	20.67			
Labtest Item 1 (Linear Air Track)					
E	7.61	7.30	213	1.90	-1.38
C	9.13	8.73			
Labtest Item 2 (Pendulum)					
E	17.01	5.14	213	.95	.97
C	16.18	7.09			
Labtest Item 3 (Light Spectra)					
E	15.62	10.18	213	.15	-.39
C	16.15	9.59			
Labtest Item 4 (Heat)					
E	7.57	2.11	213	.07	-.26
C	7.65	2.43			

TABLE 2--(CONTINUED)

Variable and Group[a]	Analysis of Variance				t-Ratio[d]
	Mean[b]	SD[b]	df	F[c]	
Labtest Item 5 (Density)					
E	7.03	5.20	213	1.48	-1.21
C	7.90	5.28			
Lab grade					
E	16.01	2.73	213	.44	.66
C	15.76	2.72			
Course grade					
E	50.89	5.79	213	1.21	1.10
C	49.98	6.32			

[a]Total E Group N = 105; total C Group N = 109. N for some measures was lower, due to a few cases of missing data.

[b]Means and SDs are given in the following manner:
SAT: percentiles
Pretest: raw score; 24 points possible
Posttest: raw score; 24 points possible
Labtest total: points; 100 points possible
Labtest items: points; 25 points possible for Items 1, 2, 3; 10 points possible for Item 4; 15 points possible for Item 5.
Lab grade: according to the sequence: A = 20, A- = 19, B+ - 18, B = 17, etc., with 9 or below indicating a failure in laboratory
Course grade: T-score

[c]No F-ratios showed significant differences; $F_{1,200}$ at .05 = 3.89; $F_{1,200}$ at .01 = 6.76.

[d]No t-ratios showed significant differences.

When comparisons were based on subgroups, students in the higher ability levels usually had significantly higher means than did students in lower ability levels. However, within a group of a given ability, the treatment effects were about the same. In other subgroup comparisons, no subgroup had consistently higher means than the other subgroup.

When results from comparisons for all subhypotheses were considered, the evidence favoring acceptance of the major hypothesis was greater than the evidence favoring rejection. Hence, the major hypothesis of this study was accepted.

Results of Attitudinal Measures

Statistical analyses were not applied to attitudinal measures. Two main questions were considered.

> Within the E Group, are there differences between student attitude toward programmed instructional materials and attitude toward conventional instructional materials?

A high percent of the students (72.6%) would prefer to use programmed materials rather than conventional materials for laboratory preparation. Nearly as many (63.2%) would recommend to a friend that he choose programmed materials if he had a choice. About the same number (68.1%) found programmed materials easier to understand than conventional materials. It was evident that students who used both kinds of laboratory materials preferred the programmed to the conventional materials.

> Did laboratory instructors find any qualitative differences between groups which used programmed instructional materials and those which used conventional materials?

Laboratory instructors found that students who used programmed materials were better prepared for laboratory activities than were students who used conventional materials. The students who had used programmed materials used their time to greater advantage in the laboratory than did students who used conventional materials. Compared to C Group students, E Group students started working in the laboratory with much less hesitation, indicated less confusion as they proceeded, and asked fewer procedural and content questions during the investigations.

Other Results

Although laboratory classes for two separate courses were utilized in this study, there seemed to be no differences which could be attributed to differences in the courses.

When comparisons were made between sexes, men received significantly higher mean scores on the posttest than did women. This might be due to higher previous knowledge on the part of men, as shown by the pretest ($F = 1.89$, not significant). It could also reflect a common notion that men are more interested in topics in physical science and are more likely to study such topics than women.

By contrast, women seemed to do better work on the measures related to laboratory activities. They had higher Labtest means ($F = .47$, not significant) and higher laboratory grades than did men ($F = 3.59$, $P < .05$). The higher achievement of women in laboratory measures was probably due to the expenditure of more effort on the part of women. Subjective observation indicated that women, more than men, were likely to be conscientious about laboratory work, and were likely to be more careful in collecting data and in writing laboratory reports.

When comparisons were made on the basis of ability, it was found that groups of higher ability levels achieved higher means than did the groups of lower ability levels. This finding further confirms the belief that students of higher mental ability are likely to achieve higher on written measures. However, it also indicates that students of higher mental ability are likely to have greater success in the concrete operations of laboratory activity than are students of lower ability.

Conclusions

1. Students can achieve equally well in physical science subject matter written evaluative measures whether they use

programmed laboratory instructional materials or conventional materials.

2. Students can achieve equally well in laboratory performance in physical science whether they use programmed or conventional laboratory instructional materials.

3. Students with higher ability levels tend to have more success in Physical Science course and laboratory work than do those with lower abilities.

4. Both students and instructors preferred programmed to conventional material.

5. Students who have used programmed instructional materials are better prepared for laboratory activities than are students who have used conventional materials.

Remarks

It appears that programmed instruction is at least as effective as conventional instruction for introducing students to laboratory investigations. At the very least, it could be used to provide variety in teaching methods. Subjective observations indicated that some students could learn better from programmed materials; others could learn better from narrative-form materials. More students preferred programmed to conventional materials. Hence, it might be worthwhile in some cases to have programmed materials available. Programs for laboratories are probably best used for presenting "difficult" topics; preparing programs for "easy" topics seems to be an unnecessary expenditure of time and effort.

There was considerable difference between the laboratory behavior of students who had used programs and those who had not. E Group students seemed to be more organized in their work and proceeded as if they knew what they were doing. They had fewer difficulties with procedures and equipment.

Properly prepared programmed instruction could be used more frequently than at present for preparing university students for laboratory activity. This would allow instructors to presume a common background of experience and working understandings of basic terminology, principles, concepts, or methods. The use of programmed instruction would not preclude the use of such newer philosophies of laboratory instruction as open-ended, discovery, or inquiry laboratories. The programs could provide any information needed for background or procedures.

Programmed materials, properly used, could reduce the need to "lecture" to students in university laboratories. Consequently, instructor time and effort could be diverted to more useful aspects of teaching--for example, individualized instruction where it is needed. Student time in the laboratory could be utilized for activities directly related to an investigation and not spent on less productive activities.

It is generally hoped that effective teaching produces desirable changes in behavior of learners. Such behavior changes should be evaluated. Hence, performance examinations should be used in the evaluative measures of science courses employing laboratory activities--whether programmed materials are used or not.

Footnotes

1. This is a report of part of a study conducted for the degree of Doctor of Philosophy in Science Education at The University of Michigan (1969). Professor Burton E. Voss was the chairman of the doctoral committee.

2. Aron, Ivan M., "Physics: A Detailed Guide to a New College Course for Non-Scientists," unpublished Ed.D dissertation, Columbia University, 1968.