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A SECOND EXPERIMENT IN SELF-INSTRUCTION IN GENERAL BIOLOGY[1]

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ABSTRACT

A study was made in 1964 of the effectiveness of college-level independent study of basic Mendelian genetics using a programed text as compared to a conventional text and both compared to traditional lecture-textbook approach. Covariance analysis of pre- and post-tests demonstrated a significant difference in mean gain scores of the programed text group over the other two; no significant difference was observed between the independent study-traditional text group and the lecture-text group, nor between freshmen and upperclassmen in any of the three groups.

To discover ways to increase instructional efficiency, ascertain course content which can be delegated to the student to learn, and identify suitable materials for independent study, the author has conducted two sets of experiments in self-instruction in introductory biology courses. The first experiment involved introductory biology students at both Earlham and Oberlin Colleges in 1959–1961 (Kormondy and Van Atta, 1962). This report concerns a similar experiment at Oberlin in December 1964. It was conducted in cooperation with the Great Lakes Colleges Association Programed Instruction Project, supported by a grant from the United States Office of Education.

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MATERIALS AND EXPERIMENTAL DESIGN

A programed text (Kormondy: *Introduction to Genetics,* McGraw-Hill Book Company, 1964) and a traditional text (Weisz: *Science of Biology*, McGraw-Hill Book Company, 2d ed., 1963) were compared as to effectiveness in independent study. In addition, these independent study modes were compared with the lecture system regularly employed in the course. The experimental design was conceived as a test of the null hypothesis that achievement based on test gain scores would show no significant differences among the three groups.

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The material included in the study is usually covered in three 50-minute lecture periods and one 3-hour laboratory period. It includes a review of mitosis, a treatment of meiosis, and a survey of fundamental Mendelian concepts in genetics (monohybrid, dihybrid and test crosses; complementary and supplementary gene interaction; polygenic and multiple allele inheritance, sex determination, linkage, and chromosome mapping). The more sophisticated and complex aspects of physiological and biochemical genetics were discussed in an additional block of three lectures which all groups attended in common.

The treatment administered to each group is given below; the size and composition by class of each group is given in table 1. Each group was requested to adhere to the procedure indicated for the group. Cooperation was excellent, resulting in only a few known instances of intergroup contamination, data for which were omitted in this analysis.

TABLE 1

Class distribution (by percentage) in experimental and control groups of students for whom both pre- and post-test scores were obtained.

Group	N	Freshman	Sophomore	Junior	Senior	Special
X	71	59.2	28.2	7.0	4.2	1.4
C–1	86	75.6	19.8	2.3	2.3	0.0
C	116	32.8	53.4	8.6	4.3	0.9

Group X—Independent study using programed text.
This group did not attend the three initial lectures on genetics and instead was assigned 15 lessons in the programed text, constituting an estimated nine hours of study (two hours of study is considered to be equivalent to one class hour).

Group C–1—Independent study using regular textbook.
This group did not attend the three initial lectures and was referred to the appropriate pages of their regular textbook for independent study.

Group C—Non-independent study.
This group attended the three initial lectures and used the textbook in each student's customary fashion. They were encouraged not to alter their ordinary learning-study pattern.

Pre- and post-test examinations were administered unannounced and simultaneously to all groups just prior to and immediately after the experimental period; the same test was used for both examinations, neither of which was anticipated by the student. The unannounced, simultaneous, and identical testing of all groups allowed assessment of the effectiveness of each technique uncontaminated by the effect of purposeful study induced by announced or staggered examinations. Performance on the genetics portion of the final examination was also tabulated, as was information relative to sources of experimental contamination such as the use of program by non-program students, etc. Analyses were made on paired pre- and post-test scores of 273 students. Not included were the scores on an additional 62 participating students who had taken only one of the two tests, owing to illness or voluntary absence on one of the two class days.

The pre- and post-test examinations each consisted of 12 multiple-choice questions selected from previous course examinations; they were approved by the six instructors who collaborated in teaching the course, following a procedure employed on all course examinations. The testing instrument was presumed thereby to be unbiased. The questions were distributed with equal emphasis

on factual information, drawing inferences from provided facts, and generalizing facts and inferences to new situations or to general principles.

The genetics portion of the final examination constituted 31% of the total examination, and was comprised of 60% multiple choice and short-answer type questions and 40% short essay; one-half the questions dealt with factual information, the remainder was equally divided between drawing inferences and extending generalizations. The material covered was about equally divided between classical and modern genetics.

RESULTS

Table 2 shows the mean pre- and post-test scores and the mean gain scores (the difference between pre- and post-test scores) for each group. Inasmuch as the groups were not initially uniform in their knowledge of genetics, an analysis of covariance was applied to determine the statistical significance of differences in the mean gain scores. Because of the initial disparity in class distribution, covariance analysis was also applied within each group to assess differences between freshmen and upperclassmen.

TABLE 2

Pre-test and post-test scores, mean gain scores, study time and correlation of study time and improvement

Group	N	Pre-test score ($\overline{X}_1 \pm \sigma$)	Post-test score ($\overline{X}_2 \pm \sigma$)	Mean gain score ($\overline{X}_2 - \overline{X}_1$)	Time $\overline{X} \pm \sigma$ (hours)	Correlation coefficient of improvement/time
X	71	29.6±16.7	70.5±20.6	40.9	9.4±3.8	.36 (NS)
C–1	86	33.7±17.7	56.7±15.6	23.0	4.5±2.4	−.06 (NS)
C	116	31.2±19.2	59.2±16.6	28.0	6.0±2.8	.08 (NS)

TABLE 3

Results of analysis of covariance of gain scores

Group	F value	Significance
X vs C–1	30.26	P<.001
X vs C	18.80	P<.001
C vs C–1	2.74	NS
X: freshmen vs upperclassmen	2.89	NS
C–1: freshmen vs upperclassmen	0.04	NS
C: freshmen vs upperclassmen	0.88	NS

The F and P values (at the 5% rejection level) of the covariance analysis appear in table 3. They show the following results: 1) Group X (independent study, programed text) is significantly different from both Group C–1 (independent study, conventional text) and C (non-independent study); 2) Group C and C–1 do not differ significantly; 3) there is no significant difference between freshmen and upperclassmen in any group.

In addition to the data on test scores, the mean number of hours of study spent by each group was computed from the students' time records (table 2). Correlation analysis of each student's study time and his mean gain score showed no significant correlation (table 2) in any group, although it approaches the 5% level of significance in Group X.

The groups were compared again at the end of the semester according to scores on the genetics portion of the term examination (table 4). These results show no real difference among the groups; no statistical analysis seemed indicated in view of the standard deviations observed. These results indicate not only that initial test score differences were obliterated, but also that no one group suffered "academic damage" by its particular learning procedure.

TABLE 4

Performance on genetics portion of term examination (as percentage of 62 points) and final term grade.

Group	N*	Final exam score $\bar{X} \pm \sigma$	Final term grade (A+=1, A=2, etc.)
X	69	54.4±14.8	6.1 (B−)
a. Used program second week	34	57.9±15.2	6.0 (B−)
b. Didn't use program second week	35	50.8±13.4	6.2 (B−)
C–1	86	48.7±13.2	6.0 (B−)
a. Used program second week	42	51.3±14.2	5.5 (B/B−)
b. Didn't use program second week	44	46.1±11.8	6.8 (B−/C+)
C	110	54.1±12.9	6.1 (B−)
a. Used program second week	44	58.2±21.8	5.6 (B/B−)
b. Didn't use program second week	66	51.8±11.1	6.4 (B−/C+)

*The disparity of numbers of students in this Table as compared to Table 2 exists because students who did not complete the questionnaire were not included in the summary.

There appeared to be an advantage to those students who used the programed text as supplementary to the second week's work (table 4). On the assumption that there might be inherent ability differences among these groups, term grades in the course were then computed. All three major groups performed comparably in the course as a whole. In Groups C and C–1, the students who earned a better average course grade had used the programed text supplementarily, and had performed better on the genetics part of the final exam. The better performance on just this portion of the exam could not, however, account for the better term grade average of this group. No correspondence between course grade difference and exam grade difference was observed in Group X.

STUDENT REACTION

Student reaction to the study methods employed during the experiment was obtained. An 18-item questionnaire, from which these data were analyzed, was completed by each student and, in most cases was returned on the day that all students resumed the traditional lecture approach; thus, they are not markedly influenced by "post-mortem" considerations.

In general, about two-thirds of the programed text group (Group X) responded favorably to that approach, although they were equally divided as to their preference of lecture over programed material. In spite of the mechanical and impersonal aspects of the technique, which was reported by many, most found that it gave a feeling of progress and of accomplishment.

The independent-regular textbook group (Group C–1) was less favorably inclined toward the programmed approach (somewhat over half) and was less positive of its effectiveness. The reactions of the traditional group (C) are, in general, similar, although they generally favored the particular method of presentation used for them.

DISCUSSION AND INTERPRETATION

The experimental group using a programed textbook in independent study performed significantly better than either of the control groups in learning a

given block of material. Although this higher test-score performance was accomplished with a greater expenditure of time, no correlation was found between study time and improvement in any of the three groups. As is well accepted, the function of study time in learning is intrinsically highly variable.

It can be argued that, had the non-independent study group (C) studied as for any exam, its performance would have been better; while this is doubtless true, it is also quite obvious that there is a marked difference between the active learning required in programed learning and the passive learning of a lecture situation. This distinction is more striking in comparing the "active" learning of the two independent study groups. It is reasonable to conclude, from the difference in these latter groups, that for effective and efficient independent study, the materials need to be adequately and appropriately designed. There is no evidence here to suggest that such adequately designed materials need to be of the programed or "teaching machine" sort.

The results strongly indicate that this particular part of introductory biology can be taught as effectively via independent study as by standard lecture methods; it is thus possible, thereby, to release time for more effective utilization of faculty talent. The same conclusions were drawn from the earlier Oberlin-Earlham study (Kormondy and Van Atta, 1962). There are undoubtedly other parts of the subject matter of general biology (and other disciplines) which can be similarly treated when suitable materials are available.

SUMMARY AND CONCLUSIONS

1. Students using a programed textbook in independent study learned more effectively than either group on independent study with a conventional textbook or a group taught in traditional lecture fashion.

2. Final examination scores on the material covered in the experiment showed that students on independent study were not adversely affected academically by this treatment.

LITERATURE CITED

Kormondy, E. J. and **E. L. Van Atta.** 1962. Experiment in self-instruction in general biology. Ohio Jour. Sci. 62: 4–10.