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ABSTRACT — This investigation compares achievement of ninth grade students in biology taught by inductive laboratory experiments, by deductive laboratory exercises, and by demonstration of inductive experiments. It appears that the inductive approach produced significantly greater attainment of attitudes of science. The emphasis of this on designing experiments and analyzing the data did not distract from the ability of students to learn and apply facts and principles. None of the instructional methods tested was found to be more effective with any particular ability range. Students in laboratory classes reacted more positively to their instruction than did those taught by the demonstration method.

Curricular innovators revising the secondary school sciences consider, among other things, that laboratory activity is an integral part of their new curricula. Several questions arise in reference to these laboratory activities. Who originates the laboratory activity? What is the source of the laboratory activity? Are these laboratory exercises or are they experiments with the attributes of a scientific endeavor? Are the activities done to verify or to discover? Do the laboratory experiments precede or follow the discussion of the principle or generalization involved? Are the aspects of inquiry, critical thinking, and related scientific attitudes being realized? The problem of this study was to compare the outcomes in a required course of ninth grade biology resulting from teaching in which instruction involved inductive laboratory experiments, or inductive demonstration experiments, or deductive laboratory activities.

The Experiment

Each student in the entire 1964-65 University of Minnesota High School ninth grade of seventy-five students, once his intelligence was determined by the *Lorge-Thorndike Intelligence Test* was randomly assigned to one of the three treatment groups in accordance with one of three ability ranges. The IQ ranges were defined to be: high, 126-150; medium, 118-125; and low, 89-117. The independent variables in the experiment were the following three treatments:

(1) INDUCTIVE LABORATORY students developed their own experimental designs to solve problems that arose in class discussions or were suggested by the teacher. The students carried out their planned experiment, drew their own conclusions and generalizations from data they had gathered.

(2) INDUCTIVE DEMONSTRATION was identical to the inductive laboratory, but, once the experiment was designed, it was demonstrated by the teacher's using enlargement devices, such as an overhead projector, micro-projector, or closed circuit television. Students drew their own generalizations from data provided by the demonstration.

(3) DEDUCTIVE LABORATORY students were exposed to a thorough presentation of a principle or generalization by the teacher, after which the students were presented with a designed activity to check or substantiate the previously discussed principle or generalization.

Dependent variables were the scores on tests in the areas of factual knowledge, application of principles, scientific attitude, reaction to the teaching treatment, and laboratory technique, with reliability coefficients, using the Hoyt technique, as follows: .88 .67, .72, .84, and .60, respectively. Pre-testing and post-testing also included the *Watson-Glaser Critical Thinking Appraisal*. The local instruments had been developed and pilot-tested the previous year. In addition to being analyzed for reliability the local tests were checked for validity, item difficulty, and ability to discriminate.

Statistical procedures included analysis of variance and analysis of co-variance, with pre-test scores as the co-variant for comparisons of means of the treatment and ability range groups, t-tests of difference between pre-test and post-test means, and Scheffe contrasts for determination of significance between treatment group means. A computer was used for determination of means, variances, analysis of variance, and analysis of co-variance, including the computation figures for testing equality of regression coefficient for the analysis of co-variance.

Other variables were minimized by assigning the test groups to the same instructor, covering the same content material, using the same textbook, and stressing the same objectives and principles. The activities were as similar as could be developed within the framework and limitations of the three treatments. They involved 44 experiments carried out in 22 weeks of instruction.

Analysis of Test Results

The indicated five per cent level of significance was established prior to the investigation for rejection of null hypotheses.

The null hypothesis of no difference between the treatment group means with respect to mental ability was accepted. There was a significant difference between ability levels of intelligence as measured by the *Lorge-Thorn-*

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dike Intelligence Test. This was considered desirable, since it was a basic part of the design.

The null hypothesis of no difference in the knowledge of facts and principles of biology was accepted on the basis of the results of analysis of co-variance. The null hypotheses for the application of principles and the *Watson-Glaser Critical Thinking Appraisal* could also be accepted on the basis of the analysis of co-variance.

All treatment groups gained significantly in their knowledge of facts, ability to apply principles, and to think critically, as judged by the Watson-Glaser test, as indicated by the t-test of differences between pre-test and post-test means. It was concluded that the three treatments were equally effective in the teaching of any of the ability level groups and the complete class with the full IQ range. On one of the subtests of the Watson-Glaser test, the evaluation of arguments, a significant difference between treatment groups means was established through application of analysis of variance. Further analysis using Scheffe's contrast technique in an attempt to locate wherein this difference lay did not provide evidence which can be considered significant. The results seemed, however, to support an advantage for the inductive treatment groups.

The null hypothesis of no difference in mean scores in *attitudes of science, reactions toward the teaching they received,* and *ability to use selected laboratory techniques* of biology was rejected for the three treatment groups in each of these tests. There was a significant difference between the means of the treatment groups for both of the inductive treatment groups to a significant level when compared with the deductive laboratory group. Post-test means were significantly higher than pre-test means for both inductive treatment groups but not for the deductive treatment group. It was concluded that instruction centered on either of the inductive treatments resulted in significant increases in scientific attitude as measured by the local instrument.

Responses to items in *reactions toward the teaching* were examined and the laboratory treatment section increased significantly over the demonstration treatment section when post-test means were compared, using analysis of variance. Generally, the laboratory treatment groups, both inductive and deductive, reacted more positively to their instruction than did the demonstration treatment group. Inductive treatment groups perceived the purpose of laboratory as a place to discover, while the deductive treatment section saw it as a place to check or to prove. Students in the deductive treatment group were aware of the structured nature of their laboratory activities, and they felt that this helped them get better grades. The inductive treatment groups were aware of their active role in devising experiments and realized that they, themselves, were able and required to use their own ideas in carrying out experiments.

Analysis of variance of the scores for all treatment groups (prior to laboratory technique instruction for the inductive demonstration group) was significantly in favor of the laboratory treatment groups on the test of the *ability to use selected laboratory techniques.* After the inductive demonstration treatment group was provided with a five-hour course in laboratory techniques, significant differences were again noted, but this time the advantage was in favor of the inductive demonstration treatment group. From this, it was concluded that students in the demonstration treatment section, immediately after instruction in laboratory techniques, were more adept in the use of laboratory techniques than were the laboratory sections' pupils who learned their techniques over the span of most of the instructional period.

Summary

The investigation compared the learning performance of all of the 1964-65 ninth grade biology students of the University of Minnesota High School taught by inductive laboratory experiments, by deductive laboratory exercises, and by demonstration of inductive experiments. Each treatment group was stratified into three ability level groups by IQ. Effectiveness of treatment was measured in terms of knowledge and application of principles of biology, scientific attitudes, laboratory techniques, and reaction of students to their instruction.

In general the inductive approaches, both laboratory and demonstration, were as effective as the deductive approach in teaching facts, application of principles, and laboratory techniques. The emphasis within the inductive treatments upon designing experiments and analyzing the data from them in no way distracted from the ability of these students to know facts and apply principles.

There was some indication that the inductive approach was more conducive to teaching the aspects of scientific inquiry, such as cause and effect relationship, making judgments after examining evidence, or evaluation of arguments.

No method or instruction was found to be more effective than any of the others with any particular ability range group in the measure of outcome of instruction. This was evidenced by findings of non-significance in all interactions.

There was no significant difference in favor of the deductive laboratory approach in any of the outcomes.

The students who performed experiments were more positive in their reactions toward class instruction than were those who watched demonstrations.