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AN INVESTIGATION OF THE RELATIVE
ACHIEVEMENTS OF THE OBJECTIVES OF
SECONDARY SCHOOL SCIENCE IN A
REPRESENTATIVE SAMPLING OF FIFTY-SIX
MINNESOTA SCHOOLS

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THE PROBLEM

This study has concerned itself with two general problems: the status of science instruction in the high schools of Minnesota, and the isolation of those factors inherent in the pupil or in the teaching situation that make for a better realization of the objectives of science instruction.

Specifically the present study had four purposes: (1) to describe the current practices in the teaching of biology and chemistry and to describe the persons who teach these subjects in terms of preparation, experience, teaching load, teaching objectives, and professional activities; (2) to determine the relative contributions of factual information, understanding of principles, scientific attitudes, and intelligence, to the understanding of the scientific method; (3) to determine which pupil factors or factors in the pupil's background contribute to the achievement of the objectives of science instruction; (4) to determine which teacher factors or factors in the teaching situation contribute to the achievement of the objectives of science instruction.

SELECTION OF THE SAMPLE

The chief weakness in past studies was the failure to obtain a truly representative sample for purposes of statistical treatment. Therefore, the present study placed particular emphasis on securing a sample of schools that might be truly representative. The 483 high schools in Minnesota were stratified into three population categories. The use of stratified sampling with selection of schools within each stratum by use of random numbers, insured that each school had an equal and independent chance of being chosen. Fifty-six schools, offering both biology and chemistry, were chosen by random selection. The total number of pupils involved was 3,332; 1,980 in biology and 1,352 in chemistry. Each school or teacher contributed in full as regards tests and schedules.

THE TEACHER SCHEDULE

The teacher schedule served two purposes: to furnish (1) a description of the current practices in the teaching of biology and chemistry, and (2) quantified data that might be used as a basis

for comparing two groups of students as to mean achievement as measured by the final examination, holding constant the factors of pre-test knowledge and intelligence.

THE TEACHERS

The 1946 teacher was a younger teacher in terms of experience and a less highly specialized but more comprehensively trained one in terms of science preparation in college as compared with the science teacher in 1923 and 1936. The median number of quarter hours of college science earned was 50.5 and 53.9 for biology and chemistry teachers respectively. The teachers as a group were lacking in understanding of the scientific method. Once out of college they had read few professional books on science or science teaching and less than half had attended professional meetings related to science teaching. The chemistry teacher had earned a median number of quarter hours of college mathematics of 23.7, 10.2 more than the biology teacher. Of the 91 teachers of biology and chemistry, 26 per cent, 36 per cent, and 38 per cent received their undergraduate degrees from universities, teachers colleges, and private colleges respectively, and 15 per cent of these had a Master's degree.

THE TEACHER'S LOAD

Teachers of biology had slightly heavier loads in terms of the number of different kinds of preparation and pupils handled per day. The chemistry teacher had about four different preparations per day and about 100 pupil contacts per day. The median size class was slightly over 20 pupils for both types of teachers. The modal period of instruction was fifty minutes.

LABORATORY INSTRUCTION

The teachers of science in this study were in the main dependent on laboratory manuals for their laboratory instruction in science, although they used a variety of other procedures. More teachers of chemistry used laboratory manuals than did the biology teachers. Most of the laboratory instruction accompanied class work and the demonstration was used as a supplement to individual or group laboratory exercises. Chemistry teachers rated their laboratory supplies higher in terms of quality and amount than was true in the case of biology. Most of the teachers indicated that they possessed standard laboratory equipment of the heavy type and sources of gas and electricity. All of the teachers indicated that their laboratories were supplied with running water, but this was the only equipment or supply so indicated. Although teachers indicated that the development of skill in the use of apparatus was one of the chief functions of the science laboratory, it was encouraging to note that careful observation, understanding and use of

the scientific method, development of scientific attitudes, and an understanding of principles, were functions of the science laboratory listed among the first ten functions. The median number of laboratory hours of instruction received per year was 33 in biology and 60 in chemistry, or slightly less than the number recommended by the teachers.

ADJUNCTS TO SCIENCE INSTRUCTION

The teachers were not making full use of aids to teaching such as the science club, the field trip, and visual aids of the projected type. Only 12 per cent of the teachers sponsored a science club and a bare majority took their students on field trips. The standard slide projector, film strip projector, and sound movie projector were the pieces of equipment most frequently available and these were used from five to ten times per year. The teachers indicated a fair supply of science books in the library. The median number of magazines on science available to students was less than two.

CURRICULUM REQUIREMENTS

A majority of the schools indicated that biology was a required subject while less than 10 per cent indicated that chemistry was a required subject.

OBJECTIVES AND PROCEDURES

The teachers as a group had little to offer as regards procedures for developing an understanding of principles, the scientific method, and scientific attitudes on the part of students. Demonstrations by the teachers, following the steps in the scientific method, and experiments in the laboratory, were the most frequently mentioned procedures indicated for each of the areas mentioned above. In general, the teachers of biology and chemistry provided no differentiation of instruction for those going on to college as contrasted to those not going on to college, and when they did it was largely quantitative in nature.

THE EXAMINATIONS

One of the problems in the present study was the construction of examinations in biology and chemistry that might be valid and reliable. Extreme care was taken to insure that the examinations measured what they purported to measure, namely: acquisition of factual information, understanding of principles, the understanding and use of the scientific method, and acquisition of scientific attitudes. The validity and reliability coefficients indicated that the tests apparently were efficient in these respects.

RESULTS OF THE STATISTICAL ANALYSIS

Histograms of the part distributions and total test distributions

coupled with descriptive measures such as kurtosis and skewness indicated that the part and total distributions were uni-modal and exhibited only a slight departure from normality. A slight departure from normality does not lower the efficiency appreciably, and no serious error for slight departure from normality is introduced into the significance levels with the tests used.

INTERCORRELATIONS AND MULTIPLE CORRELATIONS

The intercorrelations of the parts of each examination with each other revealed that the ability to understand and apply the scientific method in biological situations was accompanied chiefly by the abilities to acquire facts and principles, and that the ability to understand and apply the scientific method in chemical situations was chiefly accompanied by the ability to acquire facts. The intercorrelations for both subjects showed that the ability to acquire scientific attitudes as measured in these examinations was not highly related to the other abilities or to intellectual ability as measured.

The multiple correlations indicated that 53 per cent of the variance in the measures of scientific method had been accounted for in biology and that 64 per cent of this variance had been accounted for in chemistry. The percentage of influence of each of these factors as revealed by the squares of the regression coefficients indicated that in both biology and chemistry intellectual ability contributed the most to the understanding and use of the scientific method, and that of the remaining variables factual information in chemistry and the understanding principles in biology contributed the most to the understanding and application of the scientific method.

COMPARISON OF GROUPS AS TO ACHIEVEMENT

Fourteen comparisons were made in biology and fifteen comparisons were made in chemistry. The comparisons were made on the basis of the end scores, holding pre-test knowledge and intelligence constant, using the technique of analysis of variance and covariance. Whenever it was not possible to use the above technique, the *d* test of Behrens and Fisher was used. Whenever possible the upper one-fourth of the distribution was compared with the lower one-fourth of the distribution for any one comparison. The number of schools in each group was further reduced by one-fourth and the schools in the reduced sample were chosen by random means. In the comparisons where the upper one-fourth could not be compared with the lower one-fourth, the proportion of schools as they occurred in the original population in any one comparison was reduced by one-fourth. The schools chosen for the reduced sample were chosen by random means. The schools chosen for each group in any one comparison were tested for

homogeneity of variances and means. Some schools had to be eliminated from their respective groups in order to meet the assumptions basic to pooling. The two or three groups to be compared were tested for homogeneity of variance and regression. If the groups met the assumption of homogeneity of "within" regression coefficients the technique of covariance was applied. If they did not, the *d* test was used on the end scores only.

The results of the several comparisons indicated that the following factors were not significant in student achievement in biology, holding constant the factors of pre-test knowledge and intelligence: (1) sex, (2) size of school, (3) number of different kinds of preparation of the teacher (a teacher having a class in biology, chemistry, history, and algebra would have four preparations), (4) quarter hours of biology earned in college by the teacher, (5) the use or non-use of laboratory manuals, (6) the time of laboratory instruction (laboratory instruction preceded, accompanied, or followed class discussion), (7) the election of biology, and (8) the teacher's knowledge of the scientific method.

The results of the several comparisons revealed that on the average students achieved significantly more in biology, holding constant the factors of pre-test knowledge and intelligence, when (1) the teacher was in the upper one-fourth of the distribution in terms of total quarter hours of college science earned, (2) the teacher had graduated from a private college rather than from a university or teachers college, (3) the teacher had a Master's degree, (4) the number of laboratory hours received by the students was in the upper one-fourth of the state distribution, and (5) the students were in a class the size of which was in the upper one-fourth of the state distribution.

The factor of years of experience teaching biology proved to be non-significant in the achievement of students in biology. The test of Significance used was the *d* test using the end scores only.

The results of the several comparisons indicated that the following factors were not significant in student achievement in chemistry, holding constant the factors of pre-test knowledge and intelligence: (1) sex, (2) time of laboratory instruction, and (3) Master's degree held by the teacher.

The results of the several comparisons indicated that on the average students achieved significantly more in chemistry, holding constant the factors of pre-test knowledge and intelligence, when: (1) the teacher was in the upper one-fourth of the distribution in terms of quarter hours of college chemistry earned, (2) the pupils used a laboratory manual, (3) the pupils elected chemistry, (4) the number of laboratory hours received by the students was in the upper one-fourth of the state distribution, (5) the teacher had graduated from a university or private college rather than a teachers

college, and (6) the pupils were in a class the size of which was in the upper one-fourth of the state distribution.

Several additional comparisons in chemistry were not significant at the 1 per cent level or were not significant in all the sub-comparisons when a particular comparison had to be broken up into one or more sub-comparisons. The following tentative conclusions were drawn at the 5 per cent level or at the 1 per cent level in one of the sub-comparisons: that on the average, students achieved significantly more in chemistry, holding constant the factors of pre-test knowledge and intelligence, when: (1) the students were in a large sized school or medium sized school rather than a small sized school, (2) the teacher had ten or more years of experience teaching chemistry or when the teacher was in the upper one-fourth of the distribution in this category, (3) the teacher had one or two preparations rather than six preparations per day, and (4) the teacher's knowledge of the scientific method placed her in the upper one-fourth of that distribution.

Two of the comparisons did not lend themselves to treatment by means of the technique of analysis of variance and covariance. Therefore, the *d* test was applied to the end scores only. In addition, *d* tests applied to the pre-test scores and to the intelligence test scores, indicated that the groups to be compared were significantly different as regard to these two factors. Thus, we were able to draw only the following tentative conclusions, that on the average students achieved significantly more in chemistry, when: (1) they planned to go on to college, and (2) the teacher was in the upper one-fourth of the distribution in terms of total quarter hours of college science earned.

The findings in biology and chemistry were in complete agreement as regards these factors: (1) sex, (2) time of laboratory instruction, (3) number of laboratory hours received per student per year, and (4) class size.

INTERPRETATION OF THE STUDY

As was pointed out, two factors were held constant, namely, pupil intelligence and pre-test knowledge. It might well be that the significance or non-significance obtained in any one comparison might in part be due to the contribution of a factor or factors not controlled. However, every precaution was taken in regard to the fulfillment of randomness as a condition for the tests of significance for the rejection or acceptance of the null hypothesis tested.

IMPLICATIONS OF THE STUDY

The results of the analysis of the teacher schedule indicated that science instruction in Minnesota high schools is in need of improvement. Numerous suggestions were made by the teachers; some of these warrant serious consideration by educators in colleges and

universities directly concerned with the preparation of science teachers.

Statistical analysis of the test data revealed those factors which were significant in student achievement in science. College instructors, state officers of education, and administrators can utilize this knowledge in part if not in total in considering problems in science education.

The results of research in science education should be made available to those directly concerned with their utilization to the purpose that boys and girls may be more adequately trained in the sciences, not only for the precise purpose of training future scientists, but with the broader objective of opening new worlds of thought and endeavor to the average citizen of tomorrow. With such purpose in view, the findings and interpretations of this study were sent to each of the schools and teachers cooperating in this study.