A COMPARISON OF THE RELATIVE VALUES OF TWO METHODS OF TEACHING LABORATORY WORK IN SCHOOL CHEMISTRY[1]

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With the growth of interest in scientific education in the American high school systems of the last quarter century many changes in the approach to the subject have been observed. Particularly in the methods of teaching high school chemistry the effort has been to emphasize the true scientific approach as over against a memorization of the descriptive phases of the subject.

Every high school chemistry teacher recognizes a need for the best coordination of the laboratory and classroom discsussions not only as to the amount of time to be apportioned to each type of work but also the importance of their sequence. Science teachers must consider whether it is more advisable for the pupil to perform his laboratory experiments before class discussions of the principle, or whether the discussion should have precedence.

The objectives of this investigation are, first, to determine the method employed by the teachers of high school chemistry in Iowa and southeastern South Dakota, that is, do they present their classroom discussion matter prior to the laboratory material or vice versa, and second, to compare by analytical methods equaled groups taught by the methods referred to with emphasis on: (a) intellectual achievement of heterogeneous groups, and (b) the achievement of homogenous groups, with reference to the understanding of chemical reactions, ability to make practical applications and ability to solve problems involving chemical reactions.

In the literature, we find that Frank M. Greenlaw[2], submitted a report to the American Chemical Society which

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[1]Abstract of dissertation presented by A. L. Stentjes in partial fulfillment of the requirements for the Master of Arts degree at the University of South Dakota, July, 1939.

[2]Greenlaw, Frank H., Committee report, "Order of Precedence of Laboratory Work and Recitation in High School Chemistry". Journal of Chemical Education, V. (Oct. 1928) p. 1302.

showed that 55 per cent of the teachers answering his questionaire favored the laboratory first method as a means of introducing the pupil to new topics.

According to Otis[3] high school pupils are still children and are not able to understand chemical principles from the facts they observe when performing the laboratory experimenst before the discussion of the principle.

Norsworthy and Whitley[4] confirm the statement of Otis and state if the laboratory first method is to succeed, the teacher must use some technique to clarify and fix the objectives of the pupil at the beginning of the experiment.

In the high school at Flint Michigan, Grace Bagby[5] compared the achievement of various groups with results indicating that a change in the relative time of the class discussion and the laboratory experiment has very little effect upon the achievement of the pupil. However, her experiment did show that superior pupils achieved more when either all the discussion preceded the experiment or vice versa.

In a report by M. Parr and Mable Spencer[6] they show that the delayed recall shows a definite advantage for those pupils who were mentally prepared in recitation before attempting to perform an experiment.

Ralph E. Horton[7] after comparing two groups, one taught by the teacher demonstration and the other by the Problem Method, states in his conclusion "Neither method showed a superiority amounting to (statistical) certainty".

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[3]Otis, Arthur S., Statistical Methods in Educational Measurement, World Book Company, Yonkers. New York, 1923. pp. 145-146.

[4]Norsworthy and Whitley, The Psychology of Childhood, The Macmillian Company, New York, 1923, p. 115.

[5]Bagby, Grace, "The Correlation of Laboratory and Classroom Work in the Teaching of High School Chemistry"? Journal of Educational Research, XIX (May, 1929), pp. 336-340.

[6]Parr, Rosalie M., and Spencer, Mable, "Project Method" as quoted in, "Should the Laboratory or the Recitation have Precedence in the Teaching of High School Chemistry?", Journal of Chemical Education, VII (March, 1930) pp. 572-573.

[7]Horton, Ralph E., "Measurable Outcomes of Individual Laboratory Work in High School Chemistry", Contributions to Education, No. 303, New York: Teachers College, Columbia University. 1928.

Even though many of the present high school teachers are discussing their lessons first, some of our educators have expressed opinions in favor of allowing the pupil to perform the laboratory experiment before studying and understanding the theory of the reaction.

According to Charles De Garmo[8], it is necessary to first make some experiments to demonstrate why bodies are constrained to act in such a manner.

George R. Twiss[9] suggests that a pupil should be allowed to go into the laboratory as the scientist does, to find by observing experiments certain essential facts which he needs in the methodical investigation of a scientific problem which he cannot so conveniently or effectually find elsewhere.

A questionnaire was sent to all of the high school chemistry teachers in Iowa and southeastern South Dakota. From the thirty-seven replies recorded, twenty-seven teachers used both methods, six limit themselves to one. Of the six only using one method, five discuss the principle first and only one continuously uses the laboratory approach.

Relative to the mastery of subject matter, twelve state that the same percentage of pupils master their work in spite of the method used while fourteen are convinced that the percentage could be increased by the variation in the method of instruction. This result may be summarized by stating that at present it seems to be a matter of opinion.

Five teachers out of every six are in favor of using the discussion first method to teach the understanding of chemical principles, practical application and mathematical interpretation to high school pupils. However, we find the majority of teachers advocating the laboratory first method to develop interest in chemistry, scientific thinking, use of the library, chemistry as a hobby, and a desire to do more supplementary reading.

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[8]DeGarmo, Charles E., Principles of Secondary Education, as quoted by W. A. Millis and H. H. Millis, the Teaching of High School Subjects, The Century Company, New York, 1925. p. 291.

[9]Twiss, G. R., A Textbook in the Principles of Science Teaching, The Macmillian Company, New York, 1925, p. 127.

For the pupils of different mental levels, the teachers suggested the use of the discussion first method for the average and below average pupils and a small percentage of teachers recommended the laboratory first method for the above average pupil.

At the beginning of the second semester, January 1939, four groups of paired classes were selected according to mental age and chronological age. One pair of each group was taught by the discussion first method which included the mastery of the principle before allowing the pupils to go into the laboratory and the second pair, taught by the same teacher was taught by the laboratory first method, the pupils first doing their experiments in the laboratory and then discussing their lessons with their teacher.

The four units taught included, "The Halogen", "Nitrogen and its Oxides", "Carbon and its Oxides", and "The Colloids". Each unit was followed by a test prepared by the writer, which measured their achievement in the understanding of chemical reactions, practical application of the principle, and the mathematical interpretation of the principle.

As a supplement to the unit tests, a general achievement test was administered at the completion of all of the units. The reasons for administering this test are twofold. First it is the plan of the writer to establish the reliability of the unit tests which are very valuable in determining the objectives of this investigation. When the results of the unit tests were compared with the results of the general achievement tests on a "Scatter diagram"[10], we may conclude that the scores of the two tests are "rectilinearly" related. Second, the test was used to measure more completely the achievement of the various pupils who had been taught by the two methods.

The information obtained in the form of averages, Table I, although not the most accurate method for comparing numerical values, is nevertheless, the simplest procedure to

[10]Lindquist, E. F., A First Course in Statistics, Houghton Mifflin Company, New York, 1938, pp. 138-139.

follow, and indicates that the superior pupil achieves more in the unit tests by being allowed to perform the experiment before discussing the principle involved in practically all of the phases tested. The average group taught by the experiment first method excelled in practical application of the principle and mathematical interpretation.

TABLE I—AVERAGE SCORES FOR THE VARIOUS MENTAL LEVELS

Mental Level	Method	Understanding of Reactions	Practical Applications	Mathemetical Interpretations	Combined Achievement
Heterogeneous Grouping					
COMBINED AVERAGES OF ALL PUPILS TESTED	Laboratory First	12.8	27.3	4.9	45.0
	Discussion First	13.2	25.3	4 2	42.7
Greatest proficiency from		Disc. First	Lab First	Lab. First	Lab. First
Homogeneous Grouping					
ABOVE AVERAGE	Laboratory First	15.0	32.1	8.1	55.3
	Discussion First	15.1	29.1	6.5	50.4
Greatest proficiency from		Disc. First	Lab First	Lab. First	Lab. First
AVERAGE	Laboratory First	11.6	22 4	4.8	43.8
	Discussion First	13.4	26.7	4.2	44.4
Greatest proficiency from		Disc. First	Lab. First	Lab. First	Disc. First
BELOW AVERAGE	Laboratory First	11.6	22.4	1.8	35.9
	Discussion First	11.2	20.1	1.9	33.2
Greatest proficiency from		Lab. First	Lab First	Disc. First	Lab. First

Even though most of the present chemistry teachers have expressed very definitely that below average pupils should be taught by first discussing the principle, the results

of the tests in this investigation reveal higher averages in the understanding of reactions, practical application, and general achievement. Only in the mathematical interpretation did the average of the discussion first group excel.

When the true mean in one of the equated groups, having approximately the same average as the group with which it is compared, is higher, and the standard deviation of the scores, is smaller, we may conclude that this group in general has achieved more than the group with which it is compared.

According to this method of comparison illustrated in Table II, the heterogeneous group taught by the laboratory first method excelled in general achievement and practical application. The discussion first group shows the greatest proficiency in the understanding of chemical reactions.

When the results of the pupils with intelligence quotients of more than 110 are compared we find those taught by the laboratory first method excel in practical application and mathematical interpretation. The average group taught by this method also rank higher in both practical application and mathematical interpretation, however, the below average group could not be used for comparison.

Another standard for companion of these results rests upon a study of the reliability of the tests sums obtained in this study. To determine the reliability of the test scores, the critical ratio was used. According to Garrett[11] it is usually customary to take a critical ratio of three as indicative of complete reliability.

The Critical ratio, Table III of the scores made by the heterogeneous group are relatively high with respect to general achievement, and mathematical interpretation, with the most proficiency shown by the laboratory first method.

In the analysis of the critical rations for the homogeneous groupings, we observe the striking high figure for the superior group taught by the laboratory first method in mathematical interpretation.

[11]Garret, H. E., Statistics in Psychology and Education, Longmans, Green, and Company, New York, 1926, p. 131.

Three other sets of scores have produced reasonably high critical ratios. The superior group taught by the laboratory first method has a fairly high critical ratio with respect to practical application of the chemical principle. The average group taught by the discussion first method have a critical ratio which is approximately two. In the lower level of mentality, we observe that the critical ratio of the group taught by the laboratory first method is very near three in respect to practical application of the principle.

TABLE II—RELATIONSHIP BETWEEN MEANS AND STANDARD DEVIATIONS

	Highest Mean	Smallest Standard Deviation	Excels in Both
Heterogeneous Grouping			
General Achievement	Laboratory First	Laboratory First	Laboratory First
Understanding of Reactions	Discussion First	Discussion First	Discussion First
Practical Applications	Laboratory First	Laboratory First	Laboratory First
Mathematical Interpretation	Laboratory First	Discussion First	
Total Scores of Unit Tests	Laboratory First	Discussion First	
Homogeneous Grouping			
I. Q. Above 110			
Understanding of Reactions	Discussion First	Laboratory First	
Practical Applications	Laboratory First	Laboratory First	Laboratory First
Mathematical Interpretation	Laboratory First	Laboratory First	Laboratory First
I. Q. (100-110)			
Understanding of Reactions	Discussion First	Discussion First	Discussion First
Practical Applications	Laboratory First	Laboratory First	Laboratory First
Mathematical Interpretation	Laboratory First	Laboratory First	Laboratory First

I. Q. Below 100		
Understanding of Reactions	Laboratory First	Discussion First
Practical Applications	Laboratory First	Discussion First
Mathematical Interpretation	Laboratory First	Discussion First

TABLE III—CRITICAL RATIOS FOR PAIRED AND MIXED GROUPS

Heterogeneous Grouping

Type of Test	Method	Ave.	Diff.	S. D.	σ Ave.	σ Diff.	C. R.
General Achievement	Lab. First	59.81	5.90	12.45	1.44	2.04	2 88
	Disc. First	54.11		12.48	1.45		
Understanding of Reactions	Lab. First	13.06		3.73	0.43		
	Disc. First	13.73	0.67	3.32	0.36	0.56	1.21
Practical Applications	Lab. First	27.96	1.86	6.14	0.71	1.10	1.70
	Disc. First	26.10		7.32	0.85		
Mathematical Interpretation	Lab. First	5.65	1.55	3.75	0.43	0.61	1.72
	Disc. First	4.60		3.60	0.42		
Total Scores in Units	Lab. First	46.40	1.38	12.09	1.40	1.95	0.70
	Disc. First	45.02		11.40	1.38		
Homogeneous Grouping							
I. Q. Above 110							
Understanding of Reactions	Lab. First	15.00		2.59	0.47		
	Disc. First	15.25	0.25	2.63	0.49	0.09	0 36
Practical Application	Lab. First	32.18	1.59	4.60	0.85	1.38	1.15
	Disc. First	30.59		5.89	1.09		
Mathematical Interpretation	Lab. First	8.13	1.93	1.72	0.32	0.46	4.19
	Disc. First	6.20		1 84	0.34		
I. Q. (100-110)							
Understanding of Reactions	Lab. First	11.82		3.51	0.63		
	Disc. First	13.36	1.54	3.21	0.54	0.83	1.82
Practical Application	Lab. First	26.43	0.76	4.88	0.84	1.58	0.49
	Disc. First	25.67		5.91	1.36		
Mathematical Interpretation	Lab. First	4.82	0.61	3.10	0.54	0.78	0.78
	Disc. First	4.21		3.36	0.57		

I. Q. Below 100							
Understanding of Reactions	Lab. First	11.70	0.45	3.45	1.00	1.32	0.33
	Disc. First	11.26		3.02	0.87		
Practical Application	Lab. First	22.16	2.00	5.45	1.58	2.18	2.91
	Disc. First	20.16		5.19	1.50		
Mathematical Interpretation	Lab. First	1.83		3.23	0.93		
	Disc. First	1.92	0.09	2.63	0.75	1.18	0.07

According to the results of this investigation the majority of the high school chemistry teachers in Iowa and Southeastern South Dakota use both the laboratory first and the discussion first methods in teaching chemistry. Their choice of procedure depends solely upon the type of experiment to be studied and the objective to be gained. In most of the high schools in this locality the high school chemistry pupils are not divided according to mental ability and the various levels are taught by the same method.

An analysis of the achievement of the heterogeneous group reveals the fact that the laboratory first method of instruction is the better method to develop general achievement and mathematical interpretation of the chemical reactions.

The superior pupils taught by the laboratory first method achieved more than their intelligence equals who discussed their lessons first in general achievement, practical application of the principle, and mathematical interpretation of chemical reactions. This laboratory first method is most effective in mathematical interpretation for this group and is recommended especially for pupils who plan to receive training in college chemistry.

The pupils of average intelligence do practically as well when taught by one method as by the other although their averages are somewhat higher in favor of the laboratory first method.

The results of the pupils of below average intelligence cannot be considered statistically significant in respect to general achievement, understanding of reactions, or mathematical interpretation. However, this group taught by the laboratory first method did excel in practical application of chemical principles.