The Correlation of Laboratory and Class
Room Work in the Teaching of High School
Chemistry

By

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Chapter 1

The Purpose of the Study

Introduction

Science teachers will agree probably that in beginning natural science courses, such as are found in the ordinary high school, the class room and laboratory work should be interrelated closely; that is, on any given topic the two should run parallel, or at least one should follow the other quite closely. The committee on Chemical Education of the American Chemical Society, published in 1924¹ a Standard Minimum High School Course in Chemistry. One of the principal teaching objectives of this course is: "To develop a careful correlation between recitation and experiment". Whether the recitation should be followed by the experiment or whether it is desirable to reverse the order is not stated. If a correlation between recitation and experiment is to be accepted as desirable in the teaching of high school chemistry, it is worth while to determine from objective data what difference the order of presentation of subject matter makes to the learner. Several studies have aimed to determine children's interests in various types of science materials; the interests are then used in the selection of subject matter and in formulating methods of instruction for elementary and junior high school pupils. The interest factor has been neglected to a greater degree in formulating high school courses than in making them for elementary schools. In teaching high school chemistry, the writer purposes to determine to what extent the knowledge of results before going into the laboratory affects the pupil's interest and success in his experimental work.

1. Journal of Chemical Education, May, 1924.

If pupils do not learn as well when given previous information as when left uninformed, teaching methods should be modified in order to present the material so as to secure maximum teaching efficiency.

A study extending over a period of ten months, based upon the comparative attainments of seventy-two pupils in high school chemistry, was made by the writer in an attempt to evaluate three methods of teaching chemistry.

The Problem Defined.

The purpose of this study is to compare the relative efficiency of three methods of correlating class room and laboratory work. This study will attempt to present answers to the following questions:

1. Does interest aroused by a preview of results affect favorably the actual learning process in chemistry study;

2. Will the pupil learn more effectively if he does the experiment first and then studies related subject matter than if he is given a preview of the topic in class and then works on the experiment; will the pupil do better if he thoroughly covers the topic in the class before he does any laboratory work;

3. Is the interest aroused by one method of presentation of subject matter greater than that aroused by the other methods;

4. Which method is most efficient in instructing pupils of differing degrees of intelligence?

Chapter II

Method Employed

Pre-view of the Method.

In September, 1936, there were 450 juniors and seniors enrolled in the chemistry department of the Flint, Michigan, High Schools. Three groups of thirty pupils each were chosen by the writer from this enrollment for the study. The rotation group method which was considered adaptable to the experiment was followed. Objective tests were given and the results were used as bases for conclusions regarding the relative efficiency of the three methods. The groups were equated according to chronological age and general intelligence.

The classes were designated as A, B, and C. Class A came the first hour in the morning; class B, the second hour; while class C came immediately after the lunch hour. These periods were chosen in order to prevent teacher and pupil fatigue.

The school year was forty weeks long with approximately one week lost in getting under way in September and finishing in June. This allowed thirteen weeks for each rotation period; class A began work by class B method, and Class B by Class C method, etc. During the thirty-nine weeks, all three methods were applied to each class. Standardized tests, the Powers and ^{Gerry} Chemistry Tests and objective tests made by the writer were used to measure progress. At the expiration of the school year, the data were evaluated, and conclusions drawn.

Control of Minor Factors.

The lack of adequate testing material in chemistry affected the validity of the study to no small extent. Two of the best of the available standardized achievement tests were used; however, they contained

no questions bearing directly upon laboratory work. Because only two equivalent forms for these tests have been published, it was necessary to give each form twice; a possible carry over from one testing to another resulted. No grading was done in class, however, and since a thirteen week interval elapsed between tests, the practice effect was probably negligible. Supplementary tests were constructed by the writer but these could not be subjected to experimental tryouts; therefore, the selection of items was based only upon one person's opinion.

The number dropped from an original thirty in each class to twenty-four by the end of the school year. This decrease in enrollment was due largely to illness, changing of courses, and failures at the end of the first term. The seventy-two pupils who remained to the end of the term constitute an adequate number from which to draw suggestive conclusions, only.

Make up work was perhaps the most difficult item to control. If the pupil were absent only one day, he was not required to make up the assignment, unless he had missed a test. In such a case, the work was made up promptly upon his return. If more than two laboratory experiments were missed during a half year, they were made up at the end of the semester on Saturday. At the beginning, all pupils were expected to make up work upon their return to school by the method that their own particular group happened to be following. The bookkeeping involved in following this plan proved too difficult, and this procedure was later abandoned for all classes and pupils. The procedure which was followed in one class was duplicated in each of the others so that no one class profited more than another.

A somewhat artificial situation arose in holding the groups to one or another of the methods of instruction. For example, some topics had to be condensed to permit completion in three days, since one day was allowed for the experiment and two for recitation. In general, this time limit fitted in very well with most of the topics as given in Flint High School chemistry course. Units of subject matter which required more than three days' time for presentation either were divided into class work which required two experiments or were treated in one long experiment arranged to cover two days in the laboratory. Both plans consumed six days of time instead of three. In a few cases, only, the topic was condensed. In such instances, the class hour was divided for all classes; part of it was spent upon the topic and part upon drill material. Since this method involved only a change of the time element within the recitation, and not a change in subject-matter, the validity of the results was probably not influenced appreciably by such treatment.

In order to reduce both teacher and pupil fatigue to a minimum, the classes recited during the first and second hours in the morning and also during the period immediately following the lunch hour. The first group began work at 9:00; the second, at 10:00, and the third, at 1:45. Preceding the first hour class was a thirty minute home room period which was usually given over to study. This time allowance permitted pupil adjustment before class. A fifty-four minute lunch period gave needed relaxation during the day.

Such factors as size of classes, assignments, length of time for class and experiment, and place of meeting were controlled in the following manner: The variation in pupil enrollment in the three classes was never greater than two during the year. The variation was due

to occasional withdrawal of pupils from school, changing of courses, and failure at mid-year. Assignments were made quarterly in advance for all classes, as far as possible. These were augmented from day to day by additional suggestions which included such things as topic assignments and study questions. Study periods during the class hour were the same length for all pupils; likewise, all pupils covered the same material. The total time for class and laboratory was five fifty-four minute periods each week, every other day was spent in the laboratory. General school conditions necessitated the spending of alternate days in the laboratory whether an experiment was in progress or not.

Careful correlations between the class discussions and the experiment were made for all groups. Classes which had the recitation after the experiment were encouraged to discuss their laboratory work. Classes which did the experiment as the last part of the unit were told in advance what results they should expect and were led to make possible correlations before the experiment was performed.

Setting Up the Experiment and Securing the Data.

From a total enrollment of fourteen classes in chemistry, three groups of thirty pupils each were assigned the writer by the high school office for this study. These three classes were designated groups A, B, and C. There were composed largely of juniors with but two seniors in class A, four in class B, and five in class C. The groups were equated by the use of intelligence tests and chronological age. All pupils had been required to take the equivalent of one and one-half years of general science in the junior high school, and most of them had elected a year in biology upon entering the senior high school. Considerable knowledge

of chemistry was picked up before the pupils enrolled in chemistry. Therefore, Powers General Chemistry Test was given the first day; on the second day, Gerry's Tests of High School Chemistry were given.

The class and laboratory periods were the same length, - a total of fifty-four minutes for each. During the laboratory period, time was allowed for the pupils to set up and take down their own apparatus and to put their desks in order for the incoming class.

The pupils' manual was one written especially for Flint High School by teachers in the school. The experiment was divided into several parts and pupils "wrote up" each part immediately after they had performed it. They gave a brief statement of materials used, results observed, and reasons for the results. In order to insure brevity, not more than four lines of ordinary note book paper were used in writing each part unless instructions were otherwise given. Drawings of apparatus were required but the drawings were not labelled.

Bradbury's "First Book in Chemistry" was the basic text, and, while the material for each topic presented by Bradberry, was followed rather carefully, the arrangement of the topics was changed considerably to follow the Flint Course of Study. Exactly the same arrangement was followed in all classes.

The following plans were devised before beginning the study, and were rigidly adhered to throughout the year.

Method C, or No Laboratory Before Class Work.

LABORATORY:

An experiment was assigned. No help was given before the laboratory period unless it was requested. Drawings of apparatus were made after the experiment was completed. No demonstration of set ups of

apparatus was made.

The groups were instructed to read the entire experiment before coming to laboratory, and to underscore the name of each chemical and piece of apparatus mentioned. During the initial two weeks, and at certain periods thereafter, the writer checked the manuals to insure that this preparation was being made.

This class spent as much time in the laboratory as any other class, but because of unfamiliarity with the work the experiment was sometimes not completed. On the following day the experiment was discussed in the class-room, but no demonstrations were given of the parts which were unfinished, although the entire experiment was reviewed orally and tied up with the class-room work.

CLASS ROOM:

References were made constantly during the class period to procedures followed and results obtained in the laboratory: i.e., under the discussion for the preparations of Hydrogen, all methods were compared, and reasons were given for the selection of the one used. At the end of each two or three topics, objective tests made by the writer were administered.¹

Method 1 or One Day Pre-view in the Class Before Laboratory.

LABORATORY:

A one day pre-view of the assignment was made before the experiment but no laboratory instructions or precautions were given outside the laboratory. The preparation expected of the student for the next day was not emphasized. However, any questions which pupils asked were answered. Pupils were required to underscore the names of apparatus and chemicals in their texts before coming to the laboratory, and manuals were checked to see that this was done; this was done also for those work-

1. See pages 34-40 for samples of these tests.

ing by the O method. Drawings were handed in at the beginning of the laboratory period. No demonstration of apparatus set ups was made.

CLASS ROOM:

On the following day, the preview laboratory work was connected with class room discussion, the same plan as followed for class A.

Tests were treated in the same manner as for Class A.

Method 2. or Two Days in Class Room Followed by the Experiment.

LABORATORY:

The laboratory work varied from that of the other classes only in that it came after a complete discussion in the class room, lasting two days.

CLASS ROOM:

All class-room work was completed before the laboratory period. A topic was assigned and thoroughly covered in the class-room in addition to a pre-view of the experiment. All instructions as to procedure and precautions were given before the laboratory. Demonstrations of set ups of apparatus were given and drawings were required at the beginning of the laboratory hour. Connections between laboratory and class work were made before the laboratory work. The experiment was read over and materials underscored as in Class A. The same tests over the work were given to this class as for classes A and B.

At the end of the first thirteen weeks, the groups were given the Gorry and the Powers tests, and then the classes were rotated. The initial score was subtracted from the number of points earned, which left the net gain that accrued from the first one-third of the school year for each pupil. The same testing process was repeated at the conclusion of each thirteen weeks. The score was measured in terms of gains, or G, for each type, $G = FT - IT$, where FT = final test and IT = initial test;

G includes the total gains made on both Powers and Gerry tests.

Achievement tests in the chemistry field are few and those that exist are not well adapted to the needs of this study. The Powers test consists of sixty-seven questions and the Gerry, twenty-five, a total of ninety-two items. Two equivalent forms of each are available but it was necessary to give the tests at the beginning of the school year and each successive time of rotating the classes; four tests being required in all. Forms A were given as the initial tests, with the same forms following at the end of the first thirteen weeks. Forms B of these tests were administered at the next rotation period and at the end of the school year.

One outstanding difficulty arising from the use of these tests was their inadequacy in measuring increases in the chemical knowledge of pupils in proportion to the increased time increments. The following is an example: Pupil A with an I.Q. of 116, who scored 49 points at the close of the first 13 weeks, dropped to 45 points by the end of the 26th week; at the end of the year his final score was 73. Application of the formula, $G_2 = FT_2 - I_2^T$, showed that G_2 equalled -4. This result indicated that pupil A not only failed to learn any chemistry during the second period, but actually knew less about the subject than he did at the close of the first period. This same results obtained for a majority of the pupils and the group as a whole gave no evidence of consistent gain in knowledge of chemistry. See Table III.

The achievement tests contained a relatively large number of items pertaining to formulas and reactions. At the end of the first one-third of the school year, the classes had finished an intensive drill upon this part of the work with correspondingly high scores. A 13 week period of less rigorous drill followed, which allowed a portion of this knowledge

to drop below the limen of recall. The tests contained no items for measuring the gain along other lines. These gains, which had accrued during the second period were really significant. The pupils themselves expressed dissatisfaction with the questions covering the work of the second period, because they felt that the questions did not adequately test their knowledge of the subject. Other obstacles arose in the use of the standardized tests. There are no questions covering purely laboratory work since the aim of the tests is not to measure strictly laboratory or class achievement but simply general formation in chemistry.

Since these tests were administered with periods of more than three school months intervening in each case, the results may represent delayed response. Other objective examinations to test immediate recall were of course necessary.

The writer's own tests, totalling something over 500 questions, based upon experiment and recitation, were used as supplementary testing material. Class B followed class A into the recitation room with only a four minute interval between classes. The same tests were used for each of these groups. Class C, however, had lunch hour intervening. This made it necessary to give an additional form of the same test each time. Care was taken to construct questions of the same type and number to make the two tests equivalent. Multiple response, matching sets, and completion exercises were used, with an occasional true-false set patterned after the McClusky-Curtis type: "if false, change not more than two words to make true". No part credits were given on any questions and purely drill material, which frequently gave scores of 100, was discarded in the final results. No zeros were found throughout the year and only two marks of 100 are included in the tabulated scores. From four to five of these

tests were given during each thirteen week period, the results of which were averaged.

All classes did the same experiment and used the same materials. The only variation permitted in the various groups was the one necessitated by the change in the time of class and experiment. Notebooks were filed in the laboratory and the pupils were not allowed to take them from the room until the end of each semester.

When the pupils requested help, the instructor answered questions and gave such directions as were necessary for carrying out the laboratory work. Occasionally the written experiments were corrected during the laboratory period. Ordinarily, however, this could not be accomplished and the written accounts of the experiments were collected, checked, and returned to the pupils on the next day. The pupils were required to answer certain questions printed in the manual at the end of each experiment. These answers were written on a separate sheet of notebook paper and handed in with the account of the experiment. The "write-ups" were graded but the subjectivity of the scoring precluded the use of the grades in the study.

Two mental tests - the German Group Test, Form A, and the Otis Higher Form Self Administering, Form A - were given during the year. When the two I.Q.'s were found to vary by more than ten points, the pupils were re-tested by Form B, of the same tests.

The results of these tests were used as one element in equating the groups.

CHAPTER III

THE DATA

The Means and Deviations of the Distributions of
General Intelligence and Chronological Age.

In Table I will be found the means and deviations from the results of intelligence tests administered to the groups. Two months after the Terman group tests were given, the Terman I.Q.'s were checked by the Otis tests, and wherever the variations exceeded ten points, re-tests were made. These three classes, consisting of 24 pupils each, were equated upon the bases of chronological age and I.Q. The average of the two intelligence test results which most nearly approximated each other was taken as the I.Q. of the individual.¹

Table I.

The Means and Standard Deviations of the Distributions of
 General Intelligence and Chronological Age.²

Group	No. of Cases.	Chronological Age		General Intelligence	
		Mean	S.D.	Mean	S.D.
A	24	201.50	8.30	103.66	8.62
B	24	203.5	12.75	104.75	6.92
C	24	201.46	11.70	106.16	8.52

THE METHOD OF EQUATING GROUPS

No actual pairing was done for the three classes since the mean distributions and S.D.'s for chronological age and for general intelligence were very nearly the same.³ Groups were considered equivalent when

1. See page

2. See pages 21-25 for complete data.

3. See Table I.

the formula

$$\frac{M_1 - M_2}{(\text{SDM}_1)^2 - (\text{SDM}_2)^2}$$

was applied, and resulting quo-

tients were between 0 and 1. Table II shows these quotients. The S.D.'s show class A the least variable in age and class B somewhat less variable in I.Q. than classes A and C.

TABLE II.
Quotients of Equivalents

Groups	Chronological Age	Intelligence quotient
A with B	.58	.40
B with C	.52	.63
A with C	.014	.20

Three factors are involved in obtaining averages; groups A, B, and C; methods 0, 1, and 2; and three thirteen-week intervals, I, II, and III. The average for method 0 indicates group A's work during period I, B's work during period II, and C's work during interval III. Likewise the averages for method 1 include each group's work for a different thirteen-week interval; and the same situation holds for method 2. Each group had lower average scores upon the standardized tests after the second marking period (interval II) than after the first. Each group of course was working by a different method. The final method averages, however, include one-third of the lower scores as well as one-third of the higher marks for each group. Therefore, the averages for the total intervals I, II, III are to some degree an indication of the efficiency of the various methods.

The scores were averaged and deviations obtained for each rotation period. It will be noted that there is little uniformity in successive gains in the Powers and Gorry tests during the increasing time increments. This, the writer feels, is due largely to inadequacy of testing materials. The lowest "gain" made was -15 and since positive numbers lend themselves more readily to computation, plus 15 was added to all scores in order to bring them to 0 or above. Final outcomes are derived purely upon a comparative basis and such addition has no direct effect upon the results of the experiment.

Tables III and IV summarize the steps taken in evaluating the various methods.

Both Powers and Gorry tests were given the first day of school and at thirteen week intervals when the groups were rotated.

Table III shows means and deviations of the results.¹

See pages 32-35 for complete data for these and writer's tests.

TABLE III

MEANS AND STANDARD DEVIATIONS FOR POWERS AND GERTY TESTS

AS CALCULATED FOR EACH ROTATION PERIOD.

METHOD	0	1	2
GROUP A	G_1	G_2	G_3
MEAN	41.15	18.21	28.25
S.D.	7.98	4.56	6.02
METHOD	1	2	0
GROUP B	G_4	G_5	G_6
MEAN	40.58	18.91	26.08
S.D.	5.70	7.54	6.88
METHOD	2	0	1
GROUP C	G_7	G_8	G_9
MEAN	41.46	20.87	25.91
S.D.	6.24	5.56	6.00
METHOD	0	1	2
AV. OF MEANS	29.37	27.90	29.54
AV. OF S.D.'S	6.81	5.42	6.60

No class before laboratory or method 0 = $G_1 - G_2 - G_3$ One day class before laboratory or method 1 = $G_2 - G_4 - G_9$ Two day class before laboratory or method 2 = $G_3 - G_5 - G_7$

Table IV

THE MEANS AND STANDARD DEVIATIONS BASED UPON AVERAGES
FROM OBJECTIVE TESTS MADE BY WRITER.

METHOD	0	1	2
GROUP A	Score ₁	Score ₂	Score ₃
MEAN	79.75	68.25	65.00
S.D.	9.06	12.36	14.55
METHOD	1	2	0
GROUP B	Score ₄	Score ₅	Score ₆
MEAN	75.37	66.05	66.67
S.D.	9.64	11.2	14.40
METHOD	2	0	1
GROUP C	Score ₇	Score ₈	Score ₉
MEAN	78.60	69.62	64.50
S. D.	9.54	12.9	12.16
METHOD	0	1	2
AV. MEAN	72.01	69.12	69.80
AV. S. D.	12.12	11.45	11.86

No class before laboratory or method 0 = Score₁ plus score₆ plus score₈

One day class before laboratory or method 1 = Score₂ plus score₄ plus
score₉.

Two day class before laboratory or method 2 = Score₃ plus score₅ plus
score₇.

Table V summarizes results of all tests in terms of average means and deviations for the various methods.

TABLE V
SUMMARY OF TEST AVERAGES AND STANDARD DEVIATIONS FOR
THE THREE METHODS.

Method	Writer's tests		Powers and Gerry Tests	
	Average of Means	Average of S.D's	Average of Means ¹	Average of S.D's
0	72.01	12.12	29.38	6.61
1	69.13	11.45	27.90	5.42
2	69.83	11.76	29.54	6.60

1. These means are based upon gains each successive rotation period and are not means of scores. The true mean for each method is lower by 15 than the mean here. (See page 14).

DEVIATIONS FROM AVERAGE MEANS ACCORDING TO VARYING
NATIVE ABILITY OF PUPILS.

In order to determine whether any of the three methods was distinctly superior for instructing pupils of certain groups assembled according to mental ability¹, the deviations from the average means upon the various tests for each method were determined for each student. (See Table V for average means.)

The pupils' mental scores were then arbitrarily divided into three groups; low I.Q., including the 23 pupils below 100; medium I.Q., the 30 cases from 100-110 inclusive; and high I.Q., the 18 pupils above 111. In table VI will be found the average deviations from the means of the pupils of I.Q., below 100; of those of I.Q., 100-110; and of those above 111.

Table VI
AVERAGE DEVIATIONS FROM THE MEANS OF WRITERS TESTS MADE BY
PUPILS OF LOW, MEDIUM, AND HIGH I. Q.'S

METHOD	Writer's Tests			Powers and Gerry Tests		
	0	1	2	0	1	2
MEANS	72.01	69.12	69.83	29.38	27.90	29.54
A.D.-LOW	-6.33	-5.34	-7.25	-1.55	-2.30	-2.10
A.D.-MED.	-1.43	-.53	-1.21	-.05	-.29	-1.09
A.D.-HIGH	10.60	7.10	11.70	2.06	.62	4.79

1. Mental ability = what the Otis and Termn Tests measure.

Results Based Upon Data of the Study.

1. Intelligence Tests.

The Terman and Otis group tests of intelligence both were administered and composite scores computed from the resulting I.Q.'s (intelligence quotient) and I.B.'s (Index of Brightness).

If the two were widely divergent, another form of the same test was given, and the average of the two was considered as approximating the general intelligence. See Table I and Table II.

The three groups, A, B, and C, were found to be fairly equal in mental ability as judged by means and standard deviations. When the formula
$$\frac{M_1 - M_2}{(S D M_1)^2 \pm (S D M_2)^2}$$
 is applied and the variability in two groups is between 0 and 1, there is statistical assumption of equivalence. In no case did the difference between the groups exceed .63; therefore, groups A, B, and C, were considered equal in mental ability. The rotation method used by the study made actual pairing of pupils unnecessary.

2. Interest in Experimental Results as a Factor in the Learning of High School Chemistry.

Will the pupil learn just as well, or better, if he does the experiment first, than if he is given a pre-view of the topic in class and then works out the experiment; or if he thoroughly covers the topic in class before he does any of the laboratory work?

The method which calls for no class before laboratory or the one which had a one-day pre-view of an assignment and then the experiment, permitted the pupils no advance information whatever of results before they themselves did the experiment.

In the two days in the class-before-laboratory method, the pupils were told before the experiment what results to expect.

If the interest factor--as indicated in efficiency of teaching--plays any large part in the learning process, the results from method 0 and method 1 should more nearly approximate each other than any other combination. In Table III are composite scores for Powers and Gerry tests. Table IV gives scores for the writer's tests based upon 100 point scale.

By referring to Table III, it will be seen that method 0 for Powers and Gerry tests, has an average mean of 29.37; method 1, mean 27.90; method 11, mean 29.64.

The net gain of method 0 over method 1 = 1.48 or 5.30%

The net gain of method 2 over method 0 = .16 or .55%

The net gain of method 2 over method 1 = 1.64 or 5.80%.

Method 0 for writer's tests has an average mean of 72.01; method 1, mean 69.12; method 2, mean 69.93. See Table IV.

Method 0, for writer's tests shows slightly better results than method 1 or 2, for groups A, B, and C.

The net gain of method 0 over method 1 = 2.69 or 4.18%

The net gain of method 0 over method 2 = 2.18 or 3.12%

The net gain of method 2 over method 1 = .71 or 1.01%

The deviations are roughly equal.

The results from all tests show method 0 and method 2 somewhat superior to method 1. The higher average of method 0 over method 2 as judged by writer's tests is not corroborated by the Powers and Gerry test results. Telling all about an experiment before going into the laboratory, would seem, insofar as these results show, to have no undesirable effects upon the learn process, insofar as these measures reveal the results.

The writer feels from observing the pupils that interest in chemistry is not vitiated by a pre-view of the material before laboratory work. Indeed, the pre-view seems to actuate pupil interest in the laboratory projects.

The fact that the composite scores on Powers and Gerry tests in relationship to the various methods used so closely approximated the final results from the writer's tests serves as a check upon the results of the experiment as a whole. This fact substantiates the writer's conclusion that interest is not vitiated.

3. Evaluation of Methods for Instructing Pupils of Varying Native Ability.

The final question that the study would answer is: Does any of the methods show better results for instructing those of low native ability than for those of higher capacity? The results of the writer's tests (See Table VI) show method 1 to be somewhat better adapted to the needs of the pupils of low and average I.Q., while those of higher intelligence do better by either method 0 or method 2. The differences, however, are not marked.

The writer's tests for the low group deviate .99 less from the mean by method 1 than method 0, and 1.91 less by method 1 than by method 2.

For the medium group, method 1 is superior to method 0 by a deviation of 1.10, while method 1 is better than method 2 by .68.

For the high group, method 0 is better than method 1 by 3.50, and method 2 is better than 1 by 4.60.

Reference to Table V will show that the Powers and Gerry tests give somewhat the same results.

It may be concluded therefore, that methods 0 and 2 are somewhat

more efficient means in instructing pupils of high intelligence; method O shows the best effect when used for pupils of low intelligence. It must be remembered however, that only a small number of pupils was used in this investigation. The results will need to be substantiated by further investigations and the conclusions of this study are applicable only to the groups studied.

Chapter IV

Conclusions Based Upon This Study.

In the teaching of high school chemistry, it seems:

1. That pupils obtain better results for immediate recall by doing the experiment before the class work, but in delayed recall, pupils make slightly higher scores when the laboratory period comes after all class work.
2. That pupil interest in an experiment is either not dulled by being told in advance what is going to happen, or that diminution in interest so effected does not carry over into the learning process.
3. That telling the results of an experiment before working it out in the laboratory does not appreciably affect what the pupil learns as measured by two standardized tests.
4. That for purposes both of immediate and delayed recall, pupils having low or medium intelligence might profit slightly more by the following procedure: utilize the first day for class discussion; the second, for the experiment; the third, for class work.
5. That pupils of high intelligence do better work both in immediate and delayed recall either by completing the subject matter in the class room before going into the laboratory or by doing the experiment before having any class work whatever.

APPENDIX

Raw Data of Intelligence Tests

Cases	Age No.	Terman Score	Age No.	Otis Score	Average Age	Composite Score
1	191	152	193	114	192	153
2	205	179	207	120	206	149
3	219	154	221	111	220	132
4	196	121	202	100	199	110
5	198	155	194	105	196	130
6	187	183	183	126	185	154
7	192	159	194	113	193	136
8	203	99	205	98	204	98
9	202	122	204	101	203	111
10	222	176	224	111	223	143
11	195	127	197	100	196	113
12	193	145	195	115	194	130
13	198	162	194	111	196	136
14	203	118	205	97	204	107
15	199	194	195	129	197	162
16	198	150	200	103	199	126
17	204	116	206	102	205	109
18	207	144	209	109	208	126
19	202	89	204	85	203	87
20	195	133	197	107	196	120
21	196	129	198	103	197	116
22	211	148	213	106	212	127
23	201	167	203	113	202	140
24	196	175	198	116	197	145
25	201	153	203	107	202	130
26	200	125	196	114	198	119
27	185	163	187	103	186	133
28	184	154	186	118	185	136
29	219	158	221	117	220	137
30	186	93	188	97	187	95
31	204	160	206	110	205	135
32	215	112	217	97	216	104
33	200	153	202	107	201	130
34	200	164	202	106	201	135
35	188	165	190	108	189	136
36	183	156	185	118	184	137
37	193	177	195	116	194	146
38	202	143	198	105	200	121
39	206	130	208	99	207	114
40	214	126	216	103	215	115
41	205	177	201	109	203	143
42	198	143	200	109	199	126

Raw Data of Intelligence Tests

Cases	Age No.	Terman Score	Age No.	Otis Score	Average Age	Composite Score
43	214	125	216	98	215	111
44	205	156	203	114	204	135
45	227	119	233	98	230	108
46	193	152	195	112	194	132
47	205	125	207	99	206	112
48	221	89	223	93	222	91
49	204	194	206	124	205	159
50	187	130	189	112	188	121
51	195	184	197	121	196	152
52	188	174	190	112	189	143
53	205	118	207	100	206	109
54	182	156	184	115	183	135
55	190	182	192	121	191	151
56	195	202	197	124	196	163
57	194	124	196	107	195	115
58	191	130	193	98	192	114
59	205	136	207	101	206	118
60	193	106	195	100	194	103
61	212	138	214	98	213	118
62	240	127	242	103	241	115
63	204	188	200	122	202	155
64	204	103	206	101	205	102
65	196	132	198	109	197	120
66	210	151	212	114	211	132
67	211	119	213	100	212	109
68	208	108	210	97	209	102
69	192	102	198	98	195	100
70	190	153	192	106	191	129
71	202	141	198	109	200	125
72	196	172	198	115	197	145

The Refined Data of Intelligence Tests

Cases	Age No.	Terman I.Q.	Age No.	Otis I.B.	Average Age	Composite I. Q.
1	191	106	193	114	192	110
2	205	112	207	120	206	116
3	219	105	221	111	220	108
4	196	95	202	100	199	97
5	198	106	194	105	196	105
6	167	117	103	126	105	121
7	192	107	194	113	193	110
8	203	90	205	98	204	94
9	202	96	204	101	203	98
10	222	112	224	111	223	111
11	195	98	197	100	196	99
12	193	103	195	115	194	109
13	198	108	194	111	196	109
14	203	95	205	97	204	96
15	199	117	195	129	197	123
16	198	104	200	103	199	103
17	204	94	206	102	205	98
18	207	102	209	109	208	105
19	202	87	204	85	203	86
20	195	99	197	107	196	103
21	196	93	198	103	197	98
22	211	103	213	106	212	104
23	201	109	203	113	202	111
24	196	112	198	116	197	114
25	201	105	203	107	202	106
26	200	97	196	114	198	105
27	185	112	187	103	186	107
28	184	110	186	118	185	114
29	219	106	221	117	220	111
30	186	90	188	97	187	93
31	204	107	206	110	205	108
32	215	92	217	97	216	94
33	200	107	202	107	201	107
34	200	108	202	106	201	107
35	188	111	190	108	189	109
36	183	111	185	118	184	114
37	193	112	195	116	194	114
38	202	102	198	105	200	103
39	206	99	208	99	207	99
40	214	97	216	105	215	101
41	205	112	201	109	203	110
42	198	102	200	109	199	105
43	214	97	216	98	215	97
44	205	106	203	114	204	110
45	229	95	233	98	230	96
46	193	105	195	112	194	108

The Refined Data of Intelligence Tests

Cases	Age No.	Terman I.Q.	Age No.	Otis I.B.	Average Age	Composite I.Q.
47	205	100	207	99	206	99
48	221	79	223	93	222	86
49	204	117	266	124	205	120
50	187	101	169	112	188	106
51	195	114	197	121	196	117
52	186	113	190	112	189	112
53	205	95	207	100	206	97
54	182	112	184	115	183	113
55	190	115	192	121	191	118
56	195	119	197	124	196	121
57	194	97	196	107	195	102
58	191	99	193	98	192	98
59	205	100	207	101	206	100
60	193	91	195	100	194	95
61	212	100	214	98	213	99
62	240	97	242	103	241	100
63	204	115	200	122	202	118
64	204	90	206	101	205	95
65	196	98	198	109	197	103
66	210	104	212	114	211	109
67	211	95	213	100	212	97
68	203	92	210	97	209	94
69	192	90	198	98	195	94
70	190	105	192	106	191	105
71	202	102	198	109	200	105
72	196	110	198	115	197	112

Raw Data For Total Scores on Powers
and Gerry Tests.

Cases	Initial Test	Second Test	Third Test	Final Tests
1	6	36	53	55
2	9	49	45	73
3	4	35	35	48
4	4	19	32	53
5	8	27	31	55
6	4	29	30	44
7	3	26	27	35
8	0	28	27	32
9	5	32	31	53
10	7	37	50	66
11	4	33	41	53
12	2	37	41	59
13	5	51	37	43
14	4	16	27	40
15	2	37	42	53
16	4	50	29	40
17	7	22	21	42
18	12	36	35	48
19	2	16	24	38
20	7	30	30	39
21	6	40	47	59
22	0	24	27	34
23	9	38	40	48
24	2	34	34	49
25	3	26	43	64
26	3	34	39	57
27	11	31	38	42
28	6	35	43	42
29	5	40	39	58
30	5	36	21	35
31	0	31	36	37
32	19	35	23	40
33	6	28	34	43
34	10	28	34	45
35	1	30	40	52
36	5	34	38	50
37	9	42	45	66
38	5	31	39	64
39	6	29	31	37
40	3	43	40	52
41	6	33	37	40
42	7	26	46	52
43	3	28	24	38
44	2	25	28	38
45	2	27	35	44
46	4	32	29	33
47	6	28	32	46
48	3	20	32	37
49	3	54	31	43

Raw Data For Total Scores On Powers
And Gorry Tests.

Cases	Initial Test	Second Test	Third Test	Final Test
50	5	47	38	38
51	7	48	27	40
52	0	53	29	33
53	7	50	39	42
54	2	40	27	34
55	1	52	40	36
56	5	72	43	54
57	11	47	38	42
58	4	48	30	37
59	2	49	25	32
60	8	36	22	24
61	5	44	33	36
62	5	35	29	32
63	5	60	39	49
64	8	45	29	39
65	6	27	26	23
66	6	32	25	35
67	2	49	29	29
68	3	45	25	24
69	4	42	21	37
70	4	56	36	49
71	3	46	31	44
72	3	43	32	33

Deviations From Average Means¹ By Each Pupil
For Powers and Gerry Tests.

Case No.	I Q	0	Score			Deviations		
			1	2	0	1	2	
15	123	50.	20.	26.	20.62	-7.9	-3.54	
56	121	26.	39.	53.	-3.38	5.1	23.46	
6	121	40.	16.	29.	10.62	-11.9	-.54	
49	120	27.	26.	43.	-2.38	-1.9	13.46	
63	118	25.	26.	49.	-4.38	-1.9	19.46	
55	118	11.	31.	54.	-18.38	3.1	24.46	
51	117	28.	23.	35.	-1.38	-4.9	5.46	
2	116	55.	11.	43.	25.62	-16.9	13.46	
24	114	47.	15.	30.	17.62	-12.9	.46	
37	114	36.	49.	18.	6.62	20.1	-11.54	
36	114	27.	44.	19.	-2.38	16.1	-10.54	
28	114	14.	44.	23.	-15.38	16.1	-6.54	
54	113	22.	25.	40.	-7.38	-2.9	10.46	
52	112	19.	55.	44.	-10.38	7.1	14.46	
72	112	16.	25.	44.	-13.38	-2.9	14.46	
23	111	44.	17.	20.	14.62	-10.9	-6.54	
10	111	45.	23.	31.	15.62	.1	1.46	
29	111	34.	50.	14.	4.62	22.1	-15.54	
7	110	38.	16.	23.	8.62	-11.9	-6.54	
1	110	45.	17.	32.	15.62	-10.9	2.46	
44	110	25.	38.	18.	-4.38	10.1	-11.54	
41	110	18.	42.	19.	-11.38	14.1	-10.54	
35	109	27.	44.	25.	-2.38	16.1	-4.54	
13	109	41.	21.	21.	11.62	-6.9	-8.54	
66	109	25.	12.	54.	-4.38	-15.9	4.46	
12	109	50.	19.	33.	20.62	-8.9	3.46	
3	108	46.	15.	28.	16.62	-12.9	-1.54	
46	108	19.	43.	12.	-10.38	15.1	-17.54	
51	108	16.	38.	20.	-13.38	10.1	-9.54	
34	107	26.	35.	21.	-3.38	5.1	-8.54	
33	107	24.	37.	21.	-5.38	9.1	-8.54	
27	107	19.	35.	22.	-10.38	7.1	-7.54	
50	106	15.	24.	48.	-14.38	-3.9	18.46	
25	106	36.	38.	32.	6.62	10.1	2.46	
5	105	54.	19.	39.	4.62	-8.9	9.46	
18	105	39.	14.	28.	9.62	-13.9	-1.54	
70	105	28.	22.	47.	-1.38	-5.9	17.46	
71	105	28.	17.	43.	-1.38	-10.9	13.46	
26	105	33.	46.	20.	3.62	18.1	-9.54	
42	105	21.	34.	35.	-8.32	6.1	5.46	
22	104	39.	18.	22.	9.62	-9.9	-7.54	
38	103	40.	41.	23.	10.62	13.1	-6.54	
16	103	41.	14.	26.	11.62	-13.9	-3.54	
20	103	38.	15.	24.	6.62	-12.9	-5.54	
65	103	12.	19.	35.	-17.38	-8.9	5.46	
57	102	19.	20.	42.	-10.38	-7.9	12.46	

¹ See Table VII for Computation of Average Means.

Derivations From Average Means By Each Pupil
For Powers and Gerry Tests.

Case No.	I Q	O	Score			Deviations	
			1	2	0	1	2
40	101	27.	55.	12.	-2.38	27.1	-17.54
62	100	18.	18.	39.	-11.38	-9.9	9.46
59	100	22.	32.	38.	-7.58	4.1	8.46
47	99	29.	37.	19.	-.38	9.1	-10.54
61	99	18.	23.	43.	-11.38	-4.9	13.46
11	99	44.	23.	27.	14.62	-4.9	-2.54
39	99	21.	38.	17.	-8.38	10.1	-10.54
21	98	49.	22.	27.	19.62	-5.9	-2.54
58	98	22.	26.	41.	-7.38	-1.9	11.46
17	98	30.	14.	36.	.62	-13.9	6.46
9	98	42.	14.	37.	12.62	-13.9	7.46
67	97	15.	34.	42.	-14.38	6.1	12.46
43	97	29.	40.	11.	-.38	12.1	-19.54
4	97	30.	28.	16.	.62	.1	-13.54
53	97	18.	23.	47.	-11.38	-4.9	17.46
45	96	24.	48.	23.	-5.38	12.1	-4.54
14	96	29.	24.	28.	-.38	-3.9	-1.54
60	95	17.	27.	29.	-12.38	-.9	-.54
64	95	25.	21.	36.	-4.38	-6.9	6.46
8	94	43.	14.	20.	13.62	-13.9	-9.54
69	94	31.	20.	32.	1.62	-7.9	2.46
68	94	14.	36.	37.	-15.38	8.1	7.46
32	94	32.	31.	3.	2.62	3.1	-26.54
30	93	29.	46.	0.	-.38	18.1	-29.54
48	86	20.	32.	37.	-9.38	4.1	-2.54
19	86	29.	23.	29.	-.38	-4.9	-.54

Deviations From Average Means By Each
Pupil For Writer's Tests.

Case No.	I.Q.	Score			Deviations		
		0	1	2	0	1	2
15	123	88.8	82.75	80.4	16.79	13.63	10.57
56	121	91.5	94.6	94.8	19.49	25.48	24.97
6	121	83.2	78.75	68.4	11.19	9.63	-1.43
49	120	93.25	86.2	92.5	21.24	17.08	22.77
63	118	91.	78.4	93.6	18.99	9.28	23.77
55	118	76.5	71.2	91.8	4.49	2.08	21.97
51	117	68.25	63.	83.6	-3.76	-6.12	13.77
2	116	93.	84.25	82.	20.99	15.13	12.17
24	114	76.6	51.75	69.4	4.59	-17.37	-.43
37	114	87.4	80.	79.5	15.59	18.88	9.67
36	114	74.8	80.6	76.2	2.79	11.48	6.57
28	114	78.6	84.6	74.25	6.59	15.48	4.42
54	113	67.75	57.2	83.2	-4.26	-11.92	13.57
52	113	87.25	74.2	84.2	15.24	5.08	14.37
72	112	66.	56.6	76.8	-6.01	-12.52	6.97
23	111	85.6	65.	72.6	15.59	-4.12	2.77
10	111	91.6	83.	77.8	19.59	13.88	7.97
29	111	85.6	92.	66.5	13.59	22.88	15.67
7	110	67.2	61.25	47.2	-4.81	-7.87	-22.63
1	110	80.	76.	78.6	7.99	6.88	0.77
44	110	41.6	53.6	56.	-30.41	-15.52	-13.83
41	110	68.8	78.	74.50	-3.21	6.88	4.67
35	109	80.2	83.6	74.25	6.19	14.48	4.42
13	109	77.	64.	49.4	4.99	-5.12	-20.43
66	109	58.5	50.6	65.6	-23.51	-10.52	-4.23
12	109	67.6	83.75	89.8	15.59	14.63	19.97
3	108	77.8	70.25	64.8	5.79	1.13	-5.03
46	108	53.6	67.4	62.25	-15.41	-1.72	-7.58
31	108	59.4	73.2	59.	-12.61	4.08	-10.63
34	107	52.2	69.	54.	-19.61	-.12	-15.83
33	107	62.2	76.2	70.	-9.81	7.08	.17
27	107	58.	82.	60.25	-14.01	12.88	-8.58
50	106	71.25	65.8	81.4	-.76	-3.32	11.57
25	106	86.2	82.	73.	14.19	12.88	3.17
5	105	85.6	70.	73.	13.59	.68	3.17
18	105	87.8	64.	62.6	15.79	-6.12	-7.23
70	105	81.5	79.6	87.4	9.49	10.48	17.57
71	105	68.75	67.	75.8	-3.26	-2.12	5.97
26	105	84.4	83.2	81.	12.39	14.08	11.17
42	105	79.6	76.4	62.5	7.59	7.28	-7.33
22	104	74.8	58.25	58.4	2.79	-10.87	-11.43
38	103	76.6	72.8	76.25	4.59	3.68	6.42
16	103	78.4	74.	76.	6.39	4.88	6.17
20	103	77.8	59.	45.	5.79	-10.12	-24.83
65	103	51.75	42.2	68.6	-20.26	-26.92	-2.23
57	102	73.75	55.4	81.2	1.74	-13.72	11.37
40	101	77.8	81.2	78.75	5.79	12.08	8.92

Deviations From Average Means By Each
Pupil for Writer's Tests.

Case No.	I.Q.	0	Score		0	Deviations	
			1	2		1	2
62	100	48.	53.2	70.	-24.01	-15.92	.17
59	100	59.75	60.04	70.6	-12.26	-8.72	.77
47	99	67.6	73.2	56.	-4.41	4.08	-13.83
61	99	62.75	59.	70.6	-9.26	-10.12	.77
11	99	83.8	72.25	74.6	11.79	3.13	4.77
39	99	71.2	71.6	53.25	-.81	2.48	-16.58
21	98	91.2	89.5	87.6	19.19	20.38	17.77
58	98	60.25	63.2	77.	-11.76	-5.92	7.17
17	98	74.2	55.	43.8	2.19	-14.12	-26.03
9	98	88.6	80.	66.4	16.59	10.88	-3.43
67	97	76.75	75.4	86.	4.74	5.28	16.17
43	97	45.4	64.4	47.	-26.61	-4.72	-22.83
4	97	65.4	53.5	44.4	-6.61	-15.62	-25.43
53	97	75.25	62.	83.4	3.24	-7.12	13.57
45	96	56.8	68.8	57.75	-15.21	-.32	-12.08
14	96	58.4	45.75	47.8	-13.61	-23.37	-22.03
60	95	68.75	61.6	70.8	-3.26	-7.52	.97
64	95	65.25	60.4	67.4	-6.71	-6.72	-2.43
8	94	75.4	55.75	54.8	3.39	-13.37	-15.03
69	94	60.25	53.	64.8	-11.76	-16.12	-5.03
68	94	47.5	48.8	61.2	-24.51	-20.32	-8.63
32	94	56.2	78.8	67.	-15.81	9.68	-2.83
30	93	36.4	50.	56.	-35.61	-19.12	-13.83
48	86	59.2	70.2	48.5	-12.81	1.08	-21.33
19	86	64.	50.5	46.	-6.01	-16.62	-23.83

The Nitrogen Family, The Halogens, Silicon

Boron, and Aluminum¹ - Form A.

1. The element studied with carbon is _____.
2. Asbestos is _____.
3. Iron heated with glass turns the mixture _____.
- 4,5. Bricks are made of _____ and _____.
6. The substance used in pyrex to prevent breaking is _____.
7. Largest use for borax is _____.
- 8, 9, 10, 11. Name members of the halogen family in order of atomic weights _____.
- 12, 13. Write formulas for two acids of nitrogen. _____
_____.
14. Write the formula for phosphoric anhydride _____.
15. One source of phosphorus is _____.
16. Write the formula for a phosphorus compound used in matches _____.
17. Write the reaction for the preparation of silicon carbide
_____.
18. The substance used to make iron acid proof is _____.
19. Calcium acid phosphate is used as fertilizer because _____
_____.

1. Fill in the blanks with the word or phrase necessary to complete the sentence.

The Nitrogen Family, the Halogens, Silicon, Boron,
and Aluminum - Form A

(continued)

20. The test for arsenic is (Tell what is added, and what results).
_____.

21. A use for bismuth is _____.

22. Antimony is used in type metal because _____.

23, 24, 25. As atomic weight of the nitrogen family increases, density
_____ ability to form acids _____, metallic properties
_____.

26. The discovery of new elements has been aided by the use of the
_____ table.

27. This table was made possible by arranging elements according to
_____.

28, 29. The test for iodine is _____; for an iodide _____.

30. Write the formula for iodoform _____.

31. Tincture of iodine is _____.

32. Borax is used as a washing powder because when in solution it _____
_____.

33. A clear etching is done by _____.

The Nitrogen Family, the Halogens, Silicon,
Boron, and Aluminum¹ - Form B.

1. Silicon belongs to _____ family.
2. Soapstone is _____.
3. Cobalt heated with glass turns the mixture _____.
- 4,5. Cement is made of _____ and _____.
6. Al_2O_3 is used for _____.
7. Tests for boric acid is _____.
- 8, 9, 10, 11. Name members of N family in order of atomic weights.

-
- 12, 13. Write formulas for two acids of phosphorus _____
 14. Write the formula for nitric anhydride _____.
 15. One use for nitrogen is _____.
 16. One use for P_4S_3 is _____.
 17. Write the reaction for hydrofluoric acid on sand _____
 18. A use for carborandum is _____.
 19. Write the formula for phosphorus fertilizer _____.
 20. A test for a phosphate is (Tell what is added, and what results)

-
21. Low melting alloys contain _____.
 22. Type metal contains _____.
 - 23, 24, 25. As atomic weight of halogens increase, ability to form acids
_____, density _____ color _____.
 - 26, 27. A classification of elements has been made possible by _____
_____ table. This classification arranges elements according to
_____.

1). Fill in the blanks with the word or phrase necessary to complete the sentence.

- 28, 29. Test for bromine is _____; for bromide is _____
_____.
30. The formula for chloroform is _____.
31. A solvent for iodine is _____.
32. Borax is alkaline in solution because _____.
33. Light bulbs are etched by _____.

Indicators, Acids, Bases, and Salts¹ - Form A

1. Phenolphthalein turns red when added to an acid.
2. One acid cannot be distinguished from another acid by using an indicator.
3. An indicator may be used to distinguish a salt from an acid.
4. Litmus with a base turns red.
5. A salt may be prepared by adding an acid to a base.
6. A base usually consists of a non-metal and OH.
7. Such things as Cl^- , CO_3^{2-} , and SO_4^{2-} are called acid radicals.
8. Acids containing the prefix hydro are called ternary acids.
9. Bases always end in ide.
10. When aluminum sulphate was added to ammonium hydroxide, containing phenolphthalein, the color faded because the Al took the OH out of solution to form $\text{Al}(\text{OH})_3$.
11. When metallic sodium was put in water the Na sometimes caught fire and burned.
12. In the above reaction potassium hydroxide, a base, formed.
13. Bases taste bitter.
14. Dilution of an acid with water causes the color to fade because it spreads the OH of the acid further apart.
15. A base in solution feels soapy due to its alkaline reaction with the oil of the skin.
16. The non-metals are the base forming elements.
17. The salts of sulphuric acids are called nitrates.
18. When an acid reacts with a base, one of the products will always be water.

1. Instructions were to mark a T if the statement were true, and an F if false; if the statement were false to change not more than two words to make it true. The subject, however, was not to be changed. No credit was given for merely inserting the word not.

19. The characteristic properties of acids only appear when they are dissolved in water.

20. The ate salts correspond to the ous acids.

Indicators, Acids, Bases, and Salts¹ - Form B

1. Phenolphthalein remains colorless when added to an acid.
2. A base can be distinguished from a base by the use of an indicator.
3. An indicator may be used to distinguish a base from a salt.
4. Litmus with an acid turns blue.
5. One of the products of neutralization is always hydrogen.
6. An acid consists of a metal in combination with H.
7. Such things as Ba, Na, K and Ca are called metals.
8. Ternary acids contain oxygen.
9. Most acids end in ic.
10. A base shows its basic properties only when it is in solution.
11. When Na was put in water H was set free.
12. In the above reaction the product formed, other than hydrogen, was a salt.
13. Acids taste bitter.
14. The color of an indicator and a base fades upon dilution because the OH radicals are spread further apart.
15. A base in solution feels soapy due to the reaction of the acid H with the oil of the skin.
16. The metals are the acid forming elements.
17. The salts of hydrochloric acid are called fluorides.
18. When an acid reacts with a base, the process is called neutralization.
19. The characteristic properties of bases only appear when they are dissolved in water.

20. The ate salts correspond to the binary acids.

1. Instructions were to mark a T if the statement were true, and an F if false; if the statement were false to change not more than two words to make it true. The subject, however, was not to be changed. No credit was given for merely inserting the word not.