AN EXPERIMENTAL STUDY TO DETERMINE THE RELATIVE EFFECTIVENESS OF TWO METHODS OF TEACHING FIRST YEAR COLLEGE CHEMISTRY LABORATORY

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A C K N O W L E D G M E N T S

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An Experimental Study to Determine the Relative Effectiveness of Two Methods of Teaching First Year College Chemistry Laboratory

Problem:

Oklahoma Agricultural and Mechanical College, like many other collegiate institutions throughout the country, was facing numerous complicated and necessary adjustments, due to the increased enrollment. In the Chemistry Department these complications were the most acute at the freshman chemistry level, and particularly in the laboratory portion of these courses.

The situation was made more acute due to the inability of securing adequate teaching help, sufficient supplies of chemicals and apparatus, and providing laboratory desks and locker space. The Chemistry Department tried assigning the same laboratory locker and equipment to several students, to be used at different times during the week, with a fixed breakage fee paid by each student. Such an arrangement led to dissatisfaction, inefficiency, and wanton waste.

In order to seek a solution to some of these problems, a two-semester experimental study was inaugurated during the fall semester of 1947-48. The purpose of this study was to evaluate two methods of teaching first year college chemistry laboratory.

The questions we desired to have answered were:

1. What are the relative advantages or disadvantages of students working in groups of two in the laboratory as compared to individual laboratory work, when measured by pencil and paper tests?

2. What are the reactions of the instructors toward the two methods as determined by a questionnaire checked by the instructors at the close of each semester?

Subjects:

Six hundred and seventy-four Oklahoma A. and M. College freshmen and sophomore students, who had registered for Chemistry 114, were selected as the subjects for the experiment. The subjects were divided into five lecture sections and thirty-three quiz-laboratory classes, and were taught by three lecturers, four laboratory instructors[1], and six graduate assistants.

Toward the close of the first semester the students were pre-enrolled in Chemistry 124, and 312 of them served as the subjects for the second semester. The subjects during the second semester were assigned to five lecture sections and twenty quiz-laboratory classes. They were taught by three lecturers, four laboratory instructors, and five graduate assistants. All of the instructors and graduate assistants had a Bachelors Degree in Chemistry or its equivalent.

Parallel Method and Equating of Groups

First Semester

It was desirable to obtain from these students two approximately equal groups, the number of students per group being sufficiently large so as to have statistical significance. The groups received identical treatment throughout the course, with the exception of the manner of their laboratory work.

Sixteen of the classes, consisting of 335 students, were designated as individual classes to serve as the control group. The students in this group were to do their laboratory work by the conventional method. Each

[1] Most of the instructors taught classes for other courses during the first and second semester in addition of these experimental classes.

student was to use an individual laboratory locker and equipment to perform the experiments. The remaining 17 classes, consisting of 339 students, were designated as grouped classes to serve as the experimental group. The students in this group were to do exactly the same laboratory work as the students in the individual classes, but were to work in groups of two. These two students were to use one laboratory locker and one set of apparatus, to perform the experiments.

Four beginning courses in freshman chemistry are offered at Oklahoma A. and M. College, three of which are parallel courses designed for students who have had no previous high school chemistry training. Of the three parallel chemistry courses, the one designated as Chemistry 134 and 144 is offered for students of Agriculture; another, designated as Chemistry 113 and 123, is offered for students enrolled in the School of Home Economics; and the third, designated as Chemistry 114 and 124, is the traditional course, and is offered to students in the School of Engineering, students of Agriculture who plan to study veterinary medicine, pre-medical, pre-nursing, and science majors from the School of Arts and Sciences, and Education students who plan to teach science courses in high schools. The fourth course is a one semester course for students who have had high school chemistry, and who make a sufficiently high score on a Chemistry Placement Test. Therefore, it is reasonable to assume that students enrolling in Chemistry 114 were a select group, and should be about equal in ability and desire to succeed.

The students in both the control group and the experimental group were selected at random from the original group of students who had registered for Chemistry 114. Each group consisted of those students who, in enrolling, had scheduled their laboratory classes on fixed half-days of the week. Therefore the groups should be equivalent.

The teacher variable was reduced by assigning every quiz-laboratory instructor to an equal number of classes from each of the two groups whenever possible. The time of day variable was eliminated by assigning an equal number of classes from the two groups to the morning, afternoon, or evening laboratory sessions, but in any laboratory session the classes were all from one or the other of the groups. Table I shows the number of students from each school represented in the experiment.

Table I

Number of Students From Each School in Chemistry 114

	Control Group		Experimental Group	
	Freshmen	Sophomores	Freshmen	Sophomores
Engineering	153	30	196	26
Agriculture	71	5	56	3
Arts and Sciences	50	18	38	14
Education	1	0	1	2
Commerce	5	1	0	2
Home Economics	1	0	1	0
TOTALS	281	54	292	47

Many of the subjects were lost from the experiment during the first semester. Table II shows the number of students lost and their final disposition.

Table II

Number of Students Lost From Chemistry 114

Causes	Control Group	Experimental Group
Honorable Discharge	25	23
Incomplete Grades	4	6
Withdrew with Failing Grades	4	1
Quit Without Legal Withdrawal	4	5
TOTAL LOSS	37	35
Total Completing the Course	298	304

In order to have some check on the effectiveness of this procedure for equating the groups, after the semester was underway, the scores made on the American Council on Education Psychological Examination, which is given to all entering freshmen and new students at Oklahoma A. and M. College, were tabulated. The results are shown in Table III. These measures attest the approximate equivalents in the initial ability of the two groups.

Table III

Comparison of American Council on Education Psychological Examination Scores

	Control Group	Experimental Group
Mean	99.59	100.06
Standard Deviation	23.33	25.86
Range	31-172	31-155
Number of Subjects	281	285

t^2 value (means)[3] 0.22

t value (sigmas)[4] 1.72

[2] R. A. Fisher, The Design of Experiments, pp. 15-16, 38-43. In this study the "t value" approximately equals the critical ratio, which is defined as the difference between two measures divided by the standard error of the difference between two measures and indicates whether the difference between the two measures is a real difference or the result of chance fluctuation in random sampling.

[3] Harry E. Garrett, Statistics in Psychology and Education, pp. 198-200.

[4] Ibid, pp. 215-216.

Procedure:

First Semester

The students in each group were assigned to the laboratory lockers in alphabetical order. The students in the individual classes were each assigned an individual laboratory locker with a complete set of apparatus and equipment. The students in the grouped classes were assigned to the laboratory in groups of two, that is, two students were assigned a joint laboratory locker with one complete set of apparatus and equipment.[5]

At the initial meeting of the laboratory, the students were issued keys for their lockers and instructed to check their apparatus and equipment to see that it was complete, or to make it complete from the stocks in the storeroom. Each student of a group was issued a key to the joint laboratory locker and cooperated with his partner in checking the apparatus and equipment. The grouped students were told: that they would be jointly held responsible for all breakage and loss; they were to work out all their breakage and loss problems, or to appeal to the instructor any cases upon which they failed to agree; and that, at any time they felt it to their interest to discontinue a partnership, it could be accomplished with little effort or trouble.

At the initial meeting of the laboratory, an account in the storeroom was opened for each of the students in the individual classes, and a joint account was opened for the students in each pair in the grouped classes. The accounts were credited for one dollar per student, which the students paid at the time they paid their general fees. During the semester, apparatus and materials checked out by the students were charged to these accounts.

[5] In either of the two methods only four students were assigned to each side of the laboratory tables.

At the close of the semester, laboratory assistants checked the apparatus in each locker and the students were required to replace all lost or damaged equipment. Then the accounts were balanced and the students were required to pay the difference in cash when their breakage and loss exceeded one dollar per student. When paired students checked out apparatus from the storeroom each member was required to sign a check-out slip. At the close of the semester, or when the partnership was dissolved, each member was charged his share and could close his account independently of his partner.

Since it was the aim of this study to have a single variable, it was assumed that the weekly program of the students, consisting of two 50-minute lecture periods, one 50-minute quiz period, and a three hour laboratory period, was equivalent with the exception of the stated variable.

All the students taking Chemistry 114 and 124 at Oklahoma A. and M. College used as a text book College Chemistry by Herman T. Briscoe, Houghton Mifflin Company, New York, 1945, in which assignments were usually made two days per week, and a laboratory manual, Semimicro Laboratory Exercises in General Chemistry by Burrows, Arthur, and Smith, Macmillan Company, New York, 1946.

During the two lecture periods each week, three lecturers, lecturing to five classes of over one hundred students each, introduced all new material. For quiz and laboratory work the students were organized in sections consisting of not more than twenty-four students.

In order to give unity to the work, each student and instructor was furnished a complete syllabus of the course. The lecturers carefully followed the material as it was presented in the syllabus.

The quiz sections were designed to allow the student self-expression and were relatively informal as compared to the lectures. During the quiz sessions the instructors carefully followed the syllabus, and tried to clear up all individual difficulties and misunderstandings.

In the laboratory, the students were asked to follow the instructions as given in the laboratory manual. The laboratory manual consisted of exercises in which were listed specific apparatus and materials, preparatory questions, procedure throughout which observations were numbered, and interpretations. The laboratory exercise to be performed was assigned the previous week, and each student was expected to have answered the preparatory questions, and to have in mind the general nature of the work to be done.

At the beginning of the laboratory period, the instructor inspected each student's laboratory manual[6] and preparatory questions, and initialed the exercise indicating that the student was ready to start the laboratory work. The exercises wereshort enough for all the students to finish the procedure and observations during the laboratory period.

The procedure in the exercises was inclusive enough for the students to be able to perform the exercise with little assistance from the instructors. The procedure was followed precisely unless a change was unavoidable due to a shortage of equipment or materials. In such cases the laboratory instructors were told by the laboratory coordinator what changes to make. Thus the changes were made uniformly. The students recorded their observations on a separate paper as they were made, and at the conclusion of the procedure, they wrote in the interpretations in the space provided in the laboratory manual. This was done in the laboratory only when time permitted, otherwise they were completed before the next laboratory period.

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[6] The inspection of the laboratory manual consisted of checking to see that the student had completed the previous exercise, and had not attempted to write in the interpretations of the assigned exercise.

During the laboratory period the instructor moved continuously about the laboratory, asking such questions as would determine whether the students understood the purpose of each part of the apparatus, and if they were interpreting the results correctly. In cases where the students did not understand, they were asked such questions as would lead them to think the problem out for themselves. Helpful suggestions on equipment and laboratory technique were given whenever necessary. In the grouped classes the instructors treated each pair as an individual, and all questions and suggestions were directed at both members of the pair, and not at any specific member. The members of each pair were encouraged to discuss the work at hand and to share in all the activities.

Measurements:

First Semester

Three inter-semester one hour objective-type laboratory examinations, three inter-semester one hour objective-type theory examinations, and a final examination were used as the major measurements during the first semester. The laboratory examinations (Exhibit I) consisted of about forty multiple choice questions of five parts each, any number of which might be correct. The questions, which were furnished by the instructors, were so constructed as to attempt to measure laboratory knowledge or information only. A number of drawings and illustrations were used to bring the laboratory situations clearly into mind. The laboratory examinations were administered during the quiz period, scored by the instructors, and the scores recorded in the master roll, which was kept in the central office. The results of these examinations are shown in Tables IV, V, and VI.

Table IV

Comparison of the First Laboratory Examination in Chemistry 114

	Control Group	Experimental Group
Mean	41.45	40.96
Standard Deviation	10.05	10.85
Range	9–59	6–59
Number of Subjects	287	304

t value (means)	0.54
t value (sigmas)	1.31

Table V

Comparison of the Second Laboratory Examination in Chemistry 114

	Control Group	Experimental Group
Mean	38.49	39.51
Standard Deviation	13.75	12.90
Range	0–77	6–65
Number of Subjects	296	304

t value (means)	0.94
t value (sigmas)	1.10

Table VI

Comparison of the Third Laboratory Examination in Chemistry 114

	Control Group	Experimental Group
Mean	58.56	58.52
Standard Deviation	10.82	11.12
Range	15–80	11–85
Number of Subjects	293	300

t value (means)	0.04
t value (sigmas)	0.47

The theory examinations (Exhibit II), consisting of about forty multiple choice questions of five parts each, were written by the director of the course in cooperation with the other lecturers. These examinations were administered during the regular theory period. Each quiz-laboratory instructor scored his students' papers, and recorded the scores in the master roll. The results of these examinations are shown in Tables VII, VIII, and IX.

Table VII

Comparison of the First Theory Examination in Chemistry 114

	Control Group	Experimental Group
Mean	69.68	69.80
Standard Deviation	12.95	13.79
Range	31-92	24-94
Number of Subjects	297	305

t value (means)	0.81
t value (sigmas)	1.09

Table VIII

Comparison of the Second Theory Examination in Chemistry 114

	Control Group	Experimental Group
Mean	57.12	56.88
Standard Deviation	17.15	16.90
Range	12-98	5-95
Number of Subjects	297	302

t value (means)	0.17
t value (sigmas)	0.25

Table IX

Comparison of the Third Theory Examination in Chemistry 114

	Control Group	Experimental Group
Mean	58.88	58.89
Standard Deviation	14.94	15.05
Range	16-92	12-88
Number of Subjects	295	303
t value (means)	0.01	
t value (sigmas)	0.13	

The final examination was a two hour examination written by the director of the course, on the same basis as the theory examinations. It was administered during the regularly scheduled final examination period, scored by the quiz-laboratory instructors, and the grades recorded in the master roll. The results of the final examination are shown in Table X.

Table X

Comparison of the Final Examination in Chemistry 114

	Control Group	Experimental Group
Mean	67.28	67.26
Standard Deviation	14.63	13.49
Range	21-95	25-95
Number of Subjects	298	304
t value (means)	0.01	
t value (sigmas)	1.07	

In addition to the above measurements, a series of drop quizzes, a series of short laboratory tests, and frequent grading of laboratory reports, went to make up the course grade. At each meeting of the laboratory, following the completion of a laboratory exercise, the instructors might collect and grade the laboratory reports, or give a short quiz over the work of the previous week. The instructors enjoyed a fair degree of freedom in this respect, but understood that they were to do one or the other about eight times during the semester.

A laboratory grade was computed by allowing equal weight for the laboratory report grades, the short laboratory test grades, and a teacher's estimate of the student's laboratory ability. This grade was given equal weight with each of the three laboratory test scores. These four grades were averaged to make the laboratory grade, which counted thirty per cent of the course grade.

The drop quizzes were a series of short tests given at the beginning of the lecture periods without being previously announced. These quizzes were graded by the quiz-laboratory instructors using a key furnished by the director of the course, and the grades recorded in the master roll. A theory grade was computed by allowing the average of the drop quizzes equal weight with each of the three one-hour theory examination scores. This average made up fifty per cent of the course grade.

The final examination accounted for the remaining twenty per cent of the course grade. Results of the course grades are shown in Table XI.

Table XI

Comparison of the Course Grades in Chemistry 114

	Control Group	Experimental Group
Mean	80.83	81.02
Standard Deviation	7.63	7.83
Range	49-97	49-97
Number of Subjects	298	303

t value (means)	0.30
t value (sigmas)	0.44

Equating of Groups:

Second Semester

In order for the experiment to continue through the second semester, the students were pre-enrolled in Chemistry 124. One hundred fifty-seven of the original control group students were assigned to the new control group, and 159 of the original experimental group students were assigned to the new experimental group. Four students from each group were lost from the experiment during the second semester.

Since these groups were selected at random from the two corresponding groups of the first semester, it was assumed that they would be equivalent. As a check on this assumed equivalence, the course grades in Chemistry 114 for the students in each of the groups were tabulated and the results are shown in Table XII.

Table XII

Comparison of the Course Grades in Chemistry 114

	Control Group	Experimental Group
Mean	84.34	83.06
Standard Deviation	6.20	6.05
Range	68-97	70-97
Number of Students	153	155
t value (means)	1.84	
t value (sigmas)	0.29	

Procedure:

Second Semester

Since Chemistry 124 is a continuation of Chemistry 114 the first semester procedure was followed during the second semester.

Measurements:

Second Semester

During the second semester two one-hour laboratory examinations were used, and the American Chemical Society Cooperative General Chemistry Test, Form 1948[7] was given as a final examination. Otherwise the testing program was the same as during the first semester.

The laboratory grade was computed by the same procedure as that used the first semester, except that the grade computed from the laboratory report grades, short laboratory test grades, and a teacher's estimate of the student's laboratory ability was allowed to count forty per cent. The two one-hour laboratory examinations were to account for the remaining sixty per cent. This grade counted thirty per cent of the course grade.

Tables XIII and XIV show the comparison of the two laboratory examinations.

Table XIII

Comparison of the First Laboratory Examination in Chemistry 124

	Control Group	Experimental Group
Mean	47.64	45.55
Standard Deviation	9.90	9.85
Range	26-74	6-65
Number of Subjects	153	155

t value (means)	1.86
t value (sigmas)	0.06

[7] This test is prepared for college students jointly by the Cooperative Test Service of the American Council on Education and the American Chemical Society through its Division of Chemical Education. For a detailed account of this testing service see Journal of Chemical Education, 25 (1948), 280-82.

Table XIV

Comparison of the Second Laboratory Examination in Chemistry 124

	Control Group	Experimental Group
Mean	53.10	51.08
Standard Deviation	12.49	11.50
Range	17-76	13-76
Number of Subjects	153	153
t value (means)	1.44	
t value (sigmas)	0.92	

Tables XV, XVI, and XVII show the comparison of the three one-hour theory examinations.

Table XV

Comparison of the First Theory Examination in Chemistry 124

	Control Group	Experimental Group
Mean	48.65	45.36
Standard Deviation	14.10	13.15
Range	21-83	11-77
Number of Subjects	153	155
t value (means)	2.12	
t value (sigmas)	0.88	

Table XVI

Comparison of the Second Theory Examination in Chemistry 124

	Control Group	Experimental Group
Mean	76.59	73.33
Standard Deviation	13.15	12.65
Range	34-100	34-98
Number of Subjects	153	155
t value (means)	2.23	
t value (sigmas)	0.50	

Table XVII

Comparison of the Third Theory Examination in Chemistry 124

	Control Group	Experimental Group
Mean	63.95	64.29
Standard Deviation	16.25	14.26
Range	21-107	33-103
Number of Subjects	153	155

t value (means)	0.20
t value (sigmas)	1.62

Table XVIII shows the comparison of the laboratory grades in Chemistry 124.

Table XVIII

Comparison of the Laboratory Grades in Chemistry 124

	Control Group	Experimental Group
Mean	56.20	57.61
Standard Deviation	11.90	8.95
Range	30-96	34-79
Number of Subjects	153	154

t value (means)	1.17
t value (sigmas)	3.47

Table XIX shows the comparison of the final examination grades.

Table XIX

Comparison of the Final Examination Grades in Chemistry 124

	Control Group	Experimental Group
Mean	40.47	36.34
Standard Deviation	19.39	17.40
Range	1-110	4-84
Number of Subjects	153	154

t value (means)	1.97
t value (sigmas)	1.34

Table XX shows the comparison of the course grade in Chemistry 124.

Table XX

Comparison of the Course Grades in Chemistry 124

	Control Group	Experimental Group
Mean	81.85	80.66
Standard Deviation	8.33	6.63
Ranges	53-97	62-96
Number of Subjects	153	154

t value (means)	1.39
t value (sigmas)	2.80

Questionnaire on Laboratory Methods

No study of this kind would be complete unless some consideration was given to the attitudes and opinions of the instructors who have worked with the two methods simultaneously.

In order to determine some of the attitudes and opinions of the instructors, a short questionnaire (Exhibit III) was prepared, listing ten propositions pertaining to the two methods of teaching laboratory. At the close of each semester, the instructors were asked to check the questionnaire. A total of sixteen questionnaires were checked, nine the first semester, and seven the second semester. The propositions and results of the questionnaire are shown in Table XXI.

Table XXI

Results of the Questionnaire on Laboratory Methods

Propositions	Yes	No	No Preference
1. Working in groups makes for a more orderly laboratory class because the tables are not so crowded.	11	1	4
2. Working in groups causes too much "bickering" and "ill feelings" in the laboratory.	0	15	1
3. I find it quite difficult to prevent conversation or exchange of information otherwise, in the individual laboratory classes.	7	7	2
4. In my classes the students seemed to prefer to work in groups.	13	0	3
5. Most students working in groups finish the experiments earlier than the ones working alone.	9	1	5
6. The students enjoy working alone more than they do working in groups.	0	11	5
7. The student has a better understanding of what is being taught by the experiment when he (or she) performs the experiment with another student.	10	4	2
8. I believe the conversation between the two students in each group adds to their understanding of the experiment.	13	0	3
9. The laboratory classes are quieter and more business like when the students work individually.	5	5	6
10. In the future I prefer having my students working individually in the laboratory.	1	6	9

The results of the questionnaire show that:

(1) the laboratory instructors feel that the conversation between the two students (Proposition 8) is beneficial in helping the students to understand what is being taught by the experiment. But in Proposition 7 there was slightly less agreement that the student understood the experiment better by working with another student.

(2) The laboratory instructors felt that students preferred to work in groups (Proposition 4). This opinion was verified, although not unanimously, in Proposition 6.

(3) "The laboratory was more orderly due to the tables being less crowded" was marked Yes by a majority of the instructors (Proposition 1), but in Proposition 9 they were evenly divided between the three responses. However in Proposition 9 only five instructors said the individual laboratory was quieter and more business like.

(4) There was little bickering or ill feelings between the students in groups (Proposition 2). There seem to be more disagreement during the second semester between the members of the various groups. However, this is not shown in the combined table.

(5) More work might be covered in the laboratory classes by using the group-of-two method. Only one instructor checked No on Proposition 5. One instructor failed to mark number 5.

(6) The instructors tended to favor the group-of-two method for their future classes (Proposition 10).

Conclusions:

All the evidence indicates that the equating of the groups during the first semester was very effective. Each of the schools represented furnished a reasonably equivalent number of students to each group. The distribution of students by classes was even more striking. Table I shows that the control group contained 281 freshmen and 54 sophomores while the experimental group contained 292 freshmen and 47 sophomores. The number of subjects lost from the experiment, Table II, from each of the two groups was practically equal. Not all of the American Council on Education Psychological Examination scores were available, but an equivalent number was found for each group and Table III shows that these scores were very nearly equivalent. The data in Tables IV to X inclusive, attests to this equivalence.

The equating of the groups for the second semester was not as effective. A comparison of the course grade of all the students who completed Chemistry 114 (Table XI) and the same grades for those students who were in the experiment during the second semester (Table XII) shows that more students with low grades dropped from the control group than were lost from the experimental group. The mean of the control group was increased by 3.51 points while the mean for the experimental group shows an increase of 2.04, giving a difference in gain of 1.47 in favor of the control group. The "t" value for the means in Table XII was 1.84. When this "t" value is compared with the "t" values for the means in Tables XIII, XIV, XV, XVI, and XIX, which are 1.86, 1.44, 2.12, 2.23, and 1.97, respectively, in favor of the control group no statistically significant differences are found between the two groups. Taking this trend into consideration, it could be assumed that these groups were as effective, for the purpose at hand, as though they were actually more nearly equivalent. Although these trends and differences during the second semester are interesting, they are not statistically significant at the one per cent level.

There was no statistically significant difference found between the two methods of teaching first year college chemistry laboratory at Oklahoma A. and M. College insofar as these measurements were concerned.

It will be noted in Table XVIII, which is made up from the data in Tables XIII and XIV averaged with the laboratory grade,[7] that the instructors favored the grouped classes in assigning laboratory grades. The same tendency was shown in checking the questionnaire at the close of each semester. According to the results of the questionnaire, the instructors favored the group-of-two method and indicated that their students preferred to work in groups. There was little evidence to indicate that students cannot work together agreeably since no more than five or six pairs were separated due to disagreements during the study. The majority of these cases occured at the beginning of the second semester.

By working in groups of two, the students had more room to set up their apparatus. A mutual check of their observations enabled them to obtain better results. There was little doubt that the conversation between the two students in each group was of value in helping the student to understand the work at hand. It has always been practically impossible to prevent "grouping" and "talking" in large laboratory classes under crowded conditions, but it was possible to confine the conversation to the groups in the

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[7] The instructors computed the final laboratory grade from the short laboratory tests, the laboratory report grades, and the teacher's estimate of the student's laboratory ability, according to the instructions from the director of the course, but were required to record only the final laboratory average in the master roll. Therefore there is no record of the individual grades that went to make up this laboratory average.

group-of-two method. Since the instructor worked with two students at a time he could cover the laboratory more frequently thus materially increasing the student-teacher contact.

The group-of-two method may favor the "laboratory parasite" or it might hamper the good student by pairing him with a slow student. As to the former, the instructor must continuously be on guard against the "laboratory parasite" by either method. The latter might not be so serious, since by explaining the more complicated parts of the work to the slower student, the brighter student might grasp a better understanding himself.

Storeroom accounting was somewhat complicated by the group-of-two method since it was necessary that each of the two students sign all laboratory cards and equipment slips. This could be overcome by adapting the storeroom accounting system to this method. The group-of-two method is more economical as to laboratory locker space, chemicals, and equipment.

It was agreed, by everyone concerned, that pencil and paper tests probably are not the ultimate measure of laboratory techniques or abilities. No work of this kind will be completely satisfactory until a laboratory performance test is devised that will measure laboratory techniques and abilities, and can be administered to a laboratory class by a laboratory instructor in a given laboratory period.[8]

So long as the situation at Oklahoma A. and M. College warrants crowded laboratories with large classes and a small teaching staff, the group-of-two method would be preferable.

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[8] C. H. Boeck. "A Practical Examination of Skills and Techniques Acquired in Freshman Chemistry." Science Education, 31;5 (December, 1947), 320-324.

Summary:

No statistically significant differences were found between the two methods insofar as these measurements were concerned. According to a questionnaire checked by the instructors, the students and teachers seemed to prefer the group-of-two method. The group-of-two method is more economical as to laboratory locker space, chemicals, and equipment.

Further work might be carried out to answer such questions as:

1. Should students be paired according to ability?
2. What are the advantages or disadvantages of strong students being paired with weaker students (a) as to the strong student, (b) as to the weaker student?
3. Can more work be covered in the same length of time by using the group-of-two method?
4. What is the maximum and minimum number of students per class in the group-of-two method?
5. How much is saved in terms of chemicals and apparatus by the group-of-two method?

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APPENDIX

Figure 2 represents the set up used in the laboratory to roast cinnabar, study the drawing and answer questions 15 to 17.

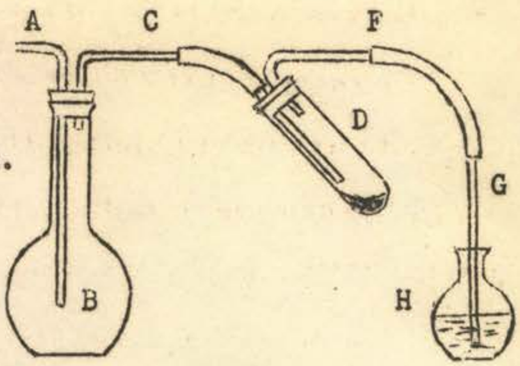

Figure 2

15. In Figure 2 the apparatus represented at:
    (1) B is a 500 ml. distilling flask.
    (2) D is a 100 mm. pyrex test tube.
    (3) H is a 50 ml. flask.
    (4) F is a rubber jointed glass delivery tube.
    (5) B is a 500 ml. Florence flask.

16. Flask B was:
    (1) filled with SO_2 at the beginning of the experiment.
    (2) Filled with water at the beginning of the experiment.
    (3) filled with water at the end of the experiment.
    (4) filled with air at the beginning of the experiment.
    (5) filled with air at the end of the experiment.

17. Which of the following are correct?
    (1) Flask H contained an acid solution at the end of the experiment.
    (2) Cinnabar was strongly heated in D.
    (3) Free mercury collected in the cooler parts of D.
    (4) Flask H was tightly stoppered to prevent gases from escaping.
    (5) A micro flame was used to heat D.

18. Which of the following might be used to shift the point of equilibrium in any equilibrium reaction?
    (1) the formation of a complex ion.
    (2) the formation of a slightly ionized product.
    (3) a reduction of the concentration of one of the reactants.
    (4) the addition of a positive catalyst.
    (5) the addition of a common ion.

19. Which of the following salt solutions will change red litmus to blue?
    (1) NaCl (2) Na_2SO_4 (3) NH_4Cl (4) $NaC_2H_3O_2$ (5) $(NH_4)_2SO_4$

20. Free carbon may be formed:
    (1) when sugar is heated moderately with a flame.
    (2) when sulfuric acid is added to sugar or starch.
    (3) by heating calcium carbonate ($CaCO_3$)
    (4) by holding a cold porcelain dish in a luminous bunsen burner flame.
    (5) by heating copper oxide with charcoal.

21. A solution with a pH of four is:
    (1) a basic solution.
    (2) more acid than a solution with a pH of six.
    (3) more basic than a solution with a pH of two.
    (4) basic to phenolphthalein.
    (5) red in litmus.

22. Which of the following will be hydrolized in water solution?
    (1) a salt formed from a strong base and a weak acid.
    (2) a salt formed by the neutralization of a strong acid by a strong base.
    (3) a salt of a weak base and a strong acid.
    (4) sodium chloride (NaCl)
    (5) Ammonium nitrate (NH_4NO_3)

9. Calcium carbonate is used commercially in:
   (1) production of quick lime.
   (2) softening hard water.
   (3) the manufacture of portland cement.
   (4) the making of glass.
   (5) none of these.

10. A solution of a metal in mercury is:
   (1) quicksilver
   (2) monel metal
   (3) an amalgam
   (4) calomel
   (5) hydroargentium

11. Sodium cyanide (NaCN) is used in the metallurgy of:
   (1) Na (2) Ag (3) Sn (4) Zn (5) Au

12. Referring to the activity chart of the metals, which of the following will be reduced by Sn, but not by Hg?
   (1) Al (2) Zn (3) K (4) Sb (5) Ag

13. An alloy:
   (1) is a heterogeneous mixture.
   (2) is a solid solution.
   (3) is an amphoteric compound.
   (4) may contain mercury as one constituent.
   (5) is an ore of gold.

14. The principal ingredients of permanent hard water are:
   (1) NaCl (2) $CaSO_4$ (3) $CaHCO_3$ (4) $MgSO_4$ (5) K_2CO_3

Five common metals are arranged in the order of their activity, the most active at the top, the least at the bottom. Use this list in answering questions 15-21.

(1) Ba (2) Mg (3) Zn (4) Cu (5) Ag

15. Which will be the most likely to occur free in nature?

16. Which forms the most stable compounds?

17. Which can be used to obtain free zinc from $ZnCl_2$?

18. Which metal along with Zn when used to form the electrodes in a simple cell will produce the highest voltage--Zn to be used as the negative pole?

19. Which two metals are the most valuable to man?

20. Which metal is commonly used to coat other metals to protect them from air?

21. Which metal was a development of the search for better aircraft?

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22. Copper:
   (1) occurs in both free state and in compounds.
   (2) deposits on the positive electrode in electrolysis of solutions of copper salts.
   (3) hydroxide is insoluble in water, but dissolves in an excess of NH_4OH solution.
   (4) salts of cupric copper are colorless in water solution.
   (5) compounds are poisonous.

23. Silver:
   (1) becomes coated with a black color when exposed to compounds of sulfur.
   (2) is soluble in hydrochloric acid.
   (3) bromide is decomposed by sunlight.
   (4) nitrate is sometimes called "lunar caustic".
   (5) is a poor conductor of heat because of its heavy weight.

CHEMISTRY 114

Questionnaire on Laboratory Methods

Exhibit III

During this semester the students in some of your laboratory classes worked in groups of two while in other classes they worked individually.

Relying on your own ideas and opinions check the following:
(This will have no bearing on your future assignments.)

	Yes	No Preference	No
1. Working in groups makes for a more orderly laboratory class because the tables are not so crowded.	___	___	___
2. Working in groups causes too much "bickering" and "ill feelings" in the laboratory.	___	___	___
3. I find it quite difficult to prevent conversation or exchange of information otherwise, in the individual laboratory classes.	___	___	___
4. In my classes the students seemed to prefer to work in groups.	___	___	___
5. Most students working in groups finish the experiments earlier than the ones working alone.	___	___	___
6. The students enjoy working alone more than they do working in groups.	___	___	___
7. The student has a better understanding of what is being taught by the experiment when he (or she) performs the experiment with another student.	___	___	___
8. I believe the conversation between the two students in each group adds to their understanding of the experiment.	___	___	___
9. The laboratory classes are quieter and more business like when the students work individually.	___	___	___
10. In the future I prefer having my students working individually in the laboratory.	___	___	___

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Typed by:

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