THE EFFECT OF THE NOTE-TEST SYSTEM OF TEACHING BASIC COLLEGE CHEMISTRY ON STUDENT ACHIEVEMENT, ATTITUDE, AND CRITICAL THINKING ABILITY

DISSERTATION

Presented to the Graduate Council of the North Texas State University in Partial Fulfillment of the Requirements

For the Degree of

DOCTOR OF EDUCATION

By

Donald Davis Collier, B.S., M.S.
Denton, Texas
December, 1970
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CHAPTER I

INTRODUCTION

As a result of his recent extensive survey of teaching introductory college chemistry, Bedson (3) gave sufficient evidence to warrant the need for a revolution in methods of teaching the basic course and in methods of educating college teachers of chemistry. He also suggested that chemistry educators examine their pedagogical practices in the hope that improved methods and techniques would increase student interest.

According to Lumsdaine,

It is quite evident that the amount of research on college teaching needs to be greatly increased even beyond the current unprecedentedly high level, achieved in part by strong support from Federal Agencies (12, p.240).

College chemistry is one of the subject matter areas which can profit from experiments designed for the evaluation of teaching methods. Although subjective evaluation of methods by recognized authorities in the field was commendable, it seemed that experimental studies would prove to be much more valuable. There appeared to be an abundant supply of subjective evaluations; however, there was an alarming lack of objective evaluations of methods in the field of chemistry.
According to Watson (24), many science teachers have not had the training, inclination, or time to engage in experimental methods of teaching. He viewed this as having been brought about by their original commitment to natural science and its teaching, together with the necessity of further training or retraining in the face of rapidly expanding scientific knowledge.

A common panacea for all classes is not likely to be forthcoming. Kooscheic (15) advised that clearly it is not possible to detail in a few summary statements the “best” method of teaching. Nevertheless, a conclusion that it does not make any difference which methods are used is clearly unjustified. Rather, recent research suggests that decisions about teaching methods do have important consequences in terms of differential achievement of the differing objectives of a course, differential effects upon different types of students, and probable differential effects depending upon other factors such as the instructor, the course content, and the over-all “climate” of the institution (13, p. 1262).

Unless the instructor of a course makes a special effort, he is likely to teach in a manner similar to that by which he was taught. This is not to say that traditional teaching should be categorized as poor teaching solely because it has been utilized for many years; much of this type instruction has been good. Nevertheless, continual striving on the part of individual teachers to upgrade the teaching process is likely to have desirable positive effects.
In many experimental studies of teaching methods, both content and method have been altered simultaneously, but not independently. As a consequence, such an approach allows us to say nothing about either separately. Thus, for example, if a modern mathematics or science program is taught by the discovery method and a traditional program by traditional methods, then, the results on any criterion variable such as problem solving ability, attitude, and the like may be due to method differences, content differences, or both in some unknown combination (20, p. 185).

The Journal of Chemical Education continues to be one of the outstanding journals for teachers of secondary and college chemistry, and by periodic reading of the journal, a chemistry teacher would have no difficulty in discovering numerous approaches to chemistry teaching. The Advisory Council on College Chemistry has also made available to many chemistry teachers a variety of modern approaches to presentation. Both the Journal of Chemical Education and the Advisory Council on College Chemistry have endeavored to encourage experimentation with new methods and have tried to stimulate publication of results. Yet, it was difficult to find records of experimental studies of suggested methods.

A recent article in the Journal of Chemical Education described the note-test system of teaching organic chemistry (23). According to the author, the system resulted in improved student achievements and attitudes. The system of presentation appeared to be a novel and promising way of teaching chemistry which, in comparison with the traditional lecture system, was actually a change in the basic concepts of presentation, coupled with continued utilization of the same content.
STATEMENT OF THE PROBLEM

The problem of this study was to determine the relative effectiveness of the note-test system and the traditional lecture system of teaching basic college chemistry.

PURPOSES OF THE STUDY

The specific purposes of this study were the following.

1. To determine the relative effectiveness of the note-test system and the traditional lecture system of teaching basic college chemistry on student achievement.

2. To determine the relative effectiveness of the note-test system and the traditional lecture system of teaching basic college chemistry on student ability to think critically and reflectively.

3. To determine the relative effectiveness of the note-test system and the traditional lecture system of teaching basic college chemistry on student attitude toward the chemistry course.

4. To determine if the relative effects of the note-test system of teaching and the traditional lecture system of teaching, on achievement, are dependent upon student ability.

5. To determine if the relative effects of the note-test system of teaching and the traditional lecture system of teaching, on critical thinking ability, are dependent upon student ability.
Hypotheses

The hypotheses tested in the study were as follows:

1. Using adjusted criterion means,
   A. Basic college chemistry students taught by the note-test system will achieve significantly higher total scores on four teacher-constructed multiple-choice examinations than will students taught by a traditional lecture method.
   B. Basic college chemistry students of the top third in student ability who have been taught by the note-test system will achieve significantly higher total scores on four teacher-constructed multiple-choice examinations than will students of the top third in student ability who have been taught by a traditional lecture method.
   C. Basic college chemistry students of the bottom third in student ability who have been taught by the note-test system will achieve significantly higher total scores on four teacher-constructed multiple-choice examinations than will students of the bottom third in student ability who have been taught by a traditional lecture method.

2. Using adjusted criterion means,
   A. Basic college chemistry students taught by the note-test system will score significantly higher on the Chemical Society-National Science Teachers Association Cooperative Examination in High School Chemistry than will students taught by a traditional lecture method.
B. Basic college chemistry students of the bottom third in student ability who have been taught by the note-test system will score significantly higher on the American Chemical Society-National Science Teachers Association Cooperative Examination in High School Chemistry than will students of the bottom third in student ability who have been taught by a traditional lecture method.

3. Using adjusted criterion means,

A. Basic college chemistry students taught by the note-test system will score significantly higher on the Glaser-Criner Critical Thinking Appraisal than will students taught by a traditional lecture method.

B. Basic college chemistry students of the top third in student ability who have been taught by the note-test system will score significantly higher on the Glaser-Criner Critical Thinking Appraisal than will students of the top third in student ability who have been taught by a traditional lecture method.

C. Basic college chemistry students of the bottom third in student ability who have been taught by the note-test system will score significantly higher on the Glaser-Criner Critical Thinking Appraisal than will students of the bottom third in student ability who have been taught by a traditional lecture method.
4. Basic college chemistry students who have been taught by the note-test system will score significantly higher on the Hard Scale of Attitudes Toward College Courses: A Scale to Study Attitudes Toward College Courses, than will students taught by a traditional lecture method.

Background and Significance of the Study

In his review of research on teaching at the college and university level, McKeechie (13) pointed out that the lecture may be an effective method of presentation, especially in cases where students vary considerably in background, ability, or interest. He suggested that feedback to the lecturer may be important. He also indicated that well organized and well presented lectures may be capable of teaching students how to apply knowledge or they may influence attitudes. He then stated that "a suspicion, supported by bits of evidence, arises that other methods of teaching may be more effective than lecturing in achieving some higher cognitive and attitudinal objectives" (13, p. 1132).

A great deal of information has been offered which discourages the continued over-utilization of the traditional lecture prevalent in the teaching of chemistry. In discussing his non-lecture approach to teaching organic chemistry, Lambert related:
My experience of auditing organic chemistry classes as a NSF faculty fellow in 1958, however, convinces me that there are few who use such approaches to presenting the material. In my travels to major institutions across the country, there were 37 conventional, dull lectures out of the 40 visited (9, p. 173).

He also criticized the lecture method with these remarks:

The standard lecture system is obsolete in organic chemistry classes smaller than 125 students. Why do instructors ignore the contributions of Johann Gutenberg to chemistry? Thanks to him, we now have movable type! A few chemists can write books which are readable. Why then do we fail to use these excellent modern texts as the principal bases for our courses (9, p. 173)?

He further expressed:

The usual lecture is a desperately sad affair viewed objectively. The instructor presents a boardful of elegantly-organized material with answers by the score, beautiful answers—to questions that the students have not asked. What is more futile than that (9, p. 174)?

Battino had the opinion that the most important function of the lecture was to serve as a pacemaker for the course and that "most learning takes place in intense and individual study sessions" (2, p. 282). He believed that most students were so preoccupied with taking notes that they were really not listening. He consequently used a system of presentation in which students were not allowed to take notes. If notes were deemed desirable by the instructor, they were prepared as a supplement for the class members.

Smith, in discussing his break with instructional tradition, wrote, "Individual study, reinforced by examinations, constitutes the heart of the course" (22, p. 148). Furthermore,
"there is time in class for soliciting students' questions and using them as springboards for discussion, which is usually more beneficial to the majority than consideration of topics pre-selected solely by the instructor" (22, p. 148). In Smith's method of teaching, "... students are required to read ahead and turn in pertinent homework problems before a topic is considered in class" (9, p. 149).

The term, "note-test" system appears to have had its origin in 1967 in the organic chemistry classes of Walter S. Trahanovsky (23) of the Department of Chemistry at the Iowa State University of Science and Technology.

A search of the literature revealed that no experimental studies of the note-test system of presentation had been done. Personal correspondence received from Trahanovsky in August 1969, indicated his belief that the note-test system could be used for freshman chemistry courses. He was, however, aware of its use in inorganic chemistry courses taught by Angelici and Verkade, both of Iowa State University.

The method of Trahanovsky (23), more than that of any other individual, stimulated the present study, and it was his article which furnished guidelines for the study. Thus a more thorough discussion relative to his instructional procedures follows.
Results of a questionnaire given to one of Trahanovsky's organic chemistry classes in 1967 indicated that students were enthusiastic and satisfied with the system. Substantial support for the belief that better student attitudes may be the result of such a system was given by Trahanovsky when he related, "In general, the system was well liked even by the very good and very poor students" (23, p. 536).

In comparing his system with that of Smith, Trahanovsky wrote, "The main differences are that a set of mimeographed notes which essentially outlines the text, is passed out and a more rigid sequence of events is followed" (23, p. 536). Also, "The advantage of this system compared to Smith's system is that it can be readily adopted by instructors and students who are used to the traditional lecture system" (23, p. 536).

Trahanovsky referred to his system, and it was truly a system of lecturing less. Three periods were devoted to covering a specific segment, referred to as a "part" by Trahanovsky, of the chemistry text. Before the first period, students were given mimeographed study sheets, including several representative problems from the text to be worked before the period.

During Period 1, the instructor covered only the highlights of the part and sometimes used demonstrations to illustrate important points. The instructor did not feel obligated to cover all important points of the part, but
assumed that students had already studied the material.

A portion of the first period was devoted to answering student questions. The second period was used as a question session in which students asked questions, either verbal or written. The questions were based on the part, the text, or the problems. During the third period, the first 30 minutes were used for a 50-point examination covering the material of the part. The balance of the period was used for discussing the examination and for handing out a new outline for another part.

Trahanovsky believed the system to be more acceptable to the students than the traditional method. To convey this, he wrote:

Based on a questionnaire, greater than 70% of the class thought that they learned more and liked the system better than the traditional system. The most common favorable comments were that they had a good set of notes, the class periods were free of frantic writing and could be used for learning, and the large number of tests forced them to keep up with the course and freed them of worry about one bad examination lowering their grade (23, p. 536).

He felt that the system resulted in better use of class time, also, that the students were more involved in the learning process. In addition, he asserted that the note-test system involved less instructor time than the traditional system for several important reasons listed in the journal article.
According to Bodson, college teachers of first-year college chemistry are in agreement on six general objectives. They are

(1) to develop the ability to do critical thinking
(2) to make the students familiar with the facts, principles, and concepts of chemistry,
(3) to help the student understand the nature of matter and its transformation,
(4) to develop the ability to handle quantitative problems,
(5) to develop intellectual honesty rather than foster the search for the "right" answer, and
(6) to teach students to be precise in observation and expression (3, p. 1).

Prior to the present experiment, it was anticipated that the note-test system would have a positive effect on attaining the important objectives. This anticipation was particularly strong with respect to the development of ability to do critical thinking. It was also thought that the note-test system would enhance the students' interests in chemistry. The primary reason for this optimistic outlook was that students in the note-test class were required to be more actively involved in class procedures and in independent study.

In his review of research on college and university teaching, McKeachie reported that "we noted that lectures usually place the learner in a passive role and that passive learning is less efficient than active" (13, p. 1133). Thus it appeared from the outset of the present study that the demand for active participation and problem-solving would eliminate most of the passivity associated with many classes.
caught in a traditional manner by lecture. It was also expected that the feedback provided the experimental class by reviewing the short quizzes immediately after the quiz session would enhance the learning process and make some extra time available for discussion purposes.

One of the aims in the experimental class of the study was to reduce the monopoly of class time by the instructor and to achieve a more student-centered learning situation.

McKeachie provided the following conjecture concerned with expectations under such conditions:

Since student-centered teaching attempts to reduce dependence upon the instructor, it would be expected to diminish his influence as a prestige figure, and probably to reduce his power to bring about attitudinal changes. However, this may be more than compensated for by increased freedom of expression and increased potency of group norms as sources of influence. Participation in discussion gives students an opportunity to gain recognition and praise which should, according to learning theory, strengthen motivation. Thistlethwaite (1960) found that National Merit Scholars checked as one of the outstanding characteristics of teachers who contributed most to their desire to learn, "allowing time for classroom discussion" (13, p. 113).

Ramsey and Howe (13) pointed out that variability in teacher characteristics may be more significant in experimental results than any imposed external arrangement. It was for this reason that the present study utilized the same instructor for both groups.

McKeachie stated that "... new methods are not usually tested except by a teacher who is enthusiastic about them. Consequently, we may be comparing student reactions
to a new method and an enthusiastic teacher with reactions to an old method taught unenthusiastically \(^7\) \((13, \text{ p. 125})\).

On the other hand, Williams \((27)\) related that a new teaching method may be at a disadvantage because it originally may be in an immature and crude state; also, teachers who use the new method may not have sufficient experience with the method.

Since it was realized that teacher enthusiasm or lack of enthusiasm, experience or lack of experience, and variability in teacher characteristics were critical variable, every effort was made to insure the success of both teaching methods of the study.

Definition of Terms

The following definitions were used for purposes of this study:

1. **Achievement** is defined as the proficiency attained by a student in Chemistry 105 as determined by the following:
   (a) The raw score made on the American Chemical Society-National Science Teachers Association Cooperative Examination in High School Chemistry, Form 1963, Advanced Version, given as a post-test and (b) the total raw score attained in Chemistry 105 by a student on one 50-item and three 40-item teacher-constructed multiple-choice examinations.

2. **ACSPR** is the abbreviation used for the American Chemical Society-National Science Teachers Association Cooperative Examination in High School Chemistry, Form 1963.
3. ACSPT is the abbreviation used for the American Chemical Society-National Science Teachers Association Cooperative Examination in High School Chemistry, Form 1963, Advanced Version, given as a post-test.

4. ACT is the abbreviation for American College Testing.

5. Adjusted mean is a mean attributed to a group on a final criterion measurement, the mean having been obtained by using specific mathematical rules for alteration of the actual mean on the criterion in a manner which takes into account a deficiency or superiority in the same group's mean on one or more supplementary measures used as concomitant variables.

A deficiency in a supplementary measure or measures will generally result in a higher adjusted mean on the final criterion than the actual mean, whereas a superiority in a supplementary measure or measures will generally result in a lower adjusted mean on the final criterion than the actual mean.

6. Attitude refers to a student's attitude toward the Chemistry 105 course, as determined by the score attained on the Hard Scale of Attitudes Toward College Courses: A Scale to Study Attitudes Toward College Courses.

7. Basic College Chemistry is Chemistry 105, a five-hour course of introductory college chemistry, taught at
Southeastern State College, which encompasses most of the basic principles of first-year college chemistry.

8. Control group was comprised of approximately half the students who took Chemistry 105 during the fall term of the 1969-1970 school year. This group was taught by a traditional lecture method, subsequently defined.

9. Critical thinking ability, as used in this study, was the ability of a student to think critically and reflectively, as determined by the score attained on the Watson-Glaser Critical Thinking Appraisal, Form B.

10. Experimental group was comprised of approximately half the students who took Chemistry 105 during the fall term of the 1969-1970 school year. This group was taught by the note-test system, subsequently defined.

11. HSA is the abbreviation for the Hand Scale of Attitudes Toward College Courses: A Scale to Study Attitudes Toward College Courses.

12. KCTOT is the abbreviation for the four teacher-constructed multiple-choice examinations consisting of 170 total items.

13. Note-Test System is a system of teaching used by Water S. Trahanovsky (23) of Iowa State University in teaching organic chemistry, which system, with two slightly altered features, was utilized in teaching an experimental class in basic college chemistry in this study. The two altered features were (1) four periods, instead of three, were used for several of the "parts", and (2) students were given
the mimeographed lecture notes and assigned problems two or three days earlier, relative to discussion of related material, than was done in Trahanovsky's classes.

Essentially, the system allotted approximately three periods to cover an appropriately selected quantity of course material. To facilitate study, the students were given mimeographed lecture notes over the material. These notes also contained assigned problems. Students were required to read the assigned material before Period 1 of each designated unit. They also handed in the previously assigned problems before class discussion of related material.

During Period 1 of each designated unit, the instructor covered the highlights of the material. Period 2 was used as a student question period, and Period 3 was used for a 30-minute examination over the material. This was followed by discussion of the examination. See Appendix P for a description of the note-test system by Trahanovsky.

13. Student-ability refers to a student's predicted score on a specific criterion. An equation for estimating the predicted score on each of three criteria was determined by multiple linear regression and correlation analysis by techniques described by Fryer (4, pp. 203-241; 4 pp. 420-430) and McNemar (14, pp. 159-167). The specific criteria referred to above were the ACSPT, NCTCT, and the WCPT.
Scores which were available before the actual class instruction began and which were utilized in the determination of the regression equations for the various criteria were ACT scores obtained from the office of the Dean of Students and scores obtained from pre-tests. The scores obtained by giving pre-tests were scores on the ACSPE and WGPR, subsequently defined.

14. Traditional lecture method, as used in this study, was a system of teaching in which continual discourse was employed by the instructor for purposes of instruction in basic college chemistry. The content of the lecture was guided by an outline, referred to as a "part", constructed by the instructor. Questions by the students were answered, but no specific effort was made to encourage questions. Some demonstrations of scientific principles were made by the instructor and some movies were shown, as in the experimental class. The most important characteristic of the presentation by the traditional lecture method was a special effort by the instructor to cover the material in the text and the outline thoroughly. Although the "part" served as the outline used by the instructor in the traditional lecture class, it was not given to the students of that class.

15. WGPR is the abbreviation used for the Watson-Glaser Critical Thinking Appraisal, Form XA, given as a pre-test.

16. WCPT is the abbreviation used for the Watson-Glaser Critical Thinking Appraisal, Form XI, given as a post-test.
Limitations of the Study

1. This study was limited to two sections of introductory college chemistry. The sections were comprised of twenty-seven students in the control group who completed the course and twenty-six students in the experimental group who completed the course. The college was a public, state-supported liberal arts college located in southeastern Oklahoma and having a total student population of approximately 2500.

2. This study was limited to instruction of both the experimental and control groups by the same instructor.

3. This study was limited to the relative effects of two teaching methods on student achievement, student attitude toward the course, and critical thinking ability.

Basic Assumptions

1. It was assumed that the attitude inventory was truthfully answered.

2. It was assumed that the difference in class times had no significant effects on results of the study. The two classes were consecutive.

3. It was assumed that students in the two classes were representative of students at Southeastern State College who ordinarily enroll in Chemistry 105.

4. It was assumed that factors other than control factors encountered in class, the laboratory, and out-of-class had no significant effects on results of the study.
5. It was assumed that any of the note-test material used by the experimental group which might have fallen into the hands of students in the control group had no significant effect on the outcome of the experiment.

Description of the Instruments

Five instruments were employed to obtain data for comparative purposes. They were the ACT test; the American Chemical Society-National Science Teachers Association Cooperative Examination in High School Chemistry, Form 1963 Advanced Version; the Watson-Glaser Critical Thinking Appraisal Form VI: the Read Scale of Attitudes Toward College Courses: A Scale to Study Attitudes Toward College Courses: and four teacher-constructed multiple-choice examinations consisting of a total of 170 items.

The ACT Card of each student was consulted in order to determine the ACT composite score. ACT composite scores are determined from the four separate scores in English, social studies, natural science, and mathematics. The ACT composite score has been used widely as one criterion for admitting students to colleges and universities. An excellent discussion of the predictive ability of the ACT scores has been given in a leading psychological journal (16).

The American Chemical Society-National Science Teachers Association Cooperative Examination in High School Chemistry, Form 1963 Advanced Version is a multiple-choice examination consisting of 70 questions which have been designed for advanced placement
courses to meet the demand for a higher level, more difficult
test (1). The examination has been recommended by the
American Chemical Society to colleges and universities as a
placement test for the standardization was .96. The
reliability coefficient estimated by the Kuder-Richardson
Formula No. 21 is .960.

It was not possible to locate a standardized examination
specifically for the purpose of evaluating only the first-
semester college chemistry course. Personal correspondence
received from the Educational Testing Service, Princeton, New
Jersey, and from the Test Specialist of the United States Armed
Forces Institute, Madion, Wisconsin, strengthened the belief
that such a standardized examination had not been published.

Justification for using the instrument stemmed from the
recommendation, by the American Chemical Society, of the
examination to colleges and universities as a placement test,
and from inspection of the examination.

The Watson-Glaser Critical Thinking Appraisal can be
of assistance in comparison of methods of teaching which
purport the ability to increase a student's ability to think
critically (7, 8). The appraisal measures five aspects of
the ability to think critically: drawing sound inferences
from a summary of facts; recognizing assumptions implied by
a statement; reasoning logically by deduction; reasoning logically by interpretation; and discriminating between strong and weak arguments (25). A split-half reliability coefficient of .85 was reported for Form YM, with 529 liberal arts freshmen as the normative group. The standard error of measurement reported for the group was 3.8 (25).

Hovland (6) reported that in using the test, practice effects had been relatively slight. Although mean differences in alternate forms of the test ranged up to approximately six points, Hovland stated that "the average improvement for a group of secondary students retested after a week was only 0.6 point" (6, p. 798).

Helmstadter reported that "... an examination of both the median item discrimination indexes and the reliabilities for the various subtests suggests that Form YM is likely to be slightly superior to Form ZM" (7, p. 255). Consequently in this study Form YM was used as both the pre-test and post-test. Other information concerning the Hovland-Glaser Critical Thinking Appraisal has been included in the section entitled, "Literature Related to Critical Thinking."

The Hand Scale of Attitudes Toward College Courses: A Scale to Study Attitudes Toward College Courses is a 45-item scale which was developed by J.A. Hand (6) to study attitudes of students toward any college course. Five hundred eighty-six college students comprised the sample used in construction
of the scale. Hand reported a split-half reliability estimate of .92 based on a sample of 100 subjects.

One 50-item and three 40-item multiple-choice examinations were administered to students of both groups, and the total score for each student was used as one criterion of achievement. Guidelines which were utilized in developing the multiple-choice examinations were found in The Improvement of Secondary Teaching (17, pp. 129-131) and in A Practical Introduction to Measurement and Evaluation (19, pp. 248-253). The scoring formula used for the multiple-choice examinations was as follows: Score = Right - Wrong/3.

The four multiple-choice examination were examined for validity by two members of the Southeastern State College Department of Physical Sciences and by the academic dean of the college, who was previously chairman of the Department of Physical Sciences. Each of the three who inspected the examinations for validity had several years experience in teaching basic college chemistry and each was familiar with the course text (21). Unanimous approval of each test item was obtained from the three. Otherwise, the item was revised or deleted.

An odd-even split-half reliability coefficient was determined separately for each of the four multiple-choice examinations. Through the use of the Spearman-Brown formula, the following values were obtained:
1. Examination No. 1, 40 items 0.86.
2. Examination No. 2, 50 items 0.87.
3. Examination No. 3, 40 items 0.73.
4. Examination No. 4, 40 items 0.87.

The ACSPT scores and the MCTGf scores gave a correlation of 0.83. This high correlation may have indicated that both instruments were measuring similar abilities, lending support to the contention that the multiple-choice examinations were valid instruments and suitable for the purpose of comparing the two groups on the criterion of achievement.

Procedures for Collecting Data

The subjects used in the study were students enrolled in two sections of Chemistry 105 during the fall term, 1969-1970, at Southeastern State College.

The two classes were taught by the same instructor, and the same text was used in both classes. By a flip of the coin, the 9:30 and 10:30 classes were designated as the control and the experimental groups respectively.

The experimental group originally consisted of 32 students, while 34 students comprised the control group. However, several students in each class dropped the course and never attended class, while several others withdrew during the first three weeks. The number of students who finished the course and were retained for comparative purposes was 26 in the experimental group and 27 in the control group. There was little difference in the two groups in terms of sex and
classification. In the control group, there were 18 males and 9 females, while in the experimental group, there were 16 males and 10 females. The control group consisted of 17 freshmen, 2 sophomores, 7 juniors, and 1 senior, while in the experimental group there were 16 freshmen, 3 sophomores, 4 juniors, and 1 senior.

In order to analyze the data by means of the covariance technique, the following information was obtained for each student:

(1) The ACT composite score, as given on the ACT cards, obtained from the office of Dean of Students.

(2) The score on the *American Chemical Society-National Science Teachers Association Cooperative Examination in High School Chemistry, Form 1963, Advanced Version*, given as a pre-test during the first week.

(3) The score on the *Watson-Glaser Critical Thinking Appraisal, Form XII*, given as a pre-test during the first week.

(4) The total score on one 50-item and three 40-item teacher-constructed multiple-choice examinations given during the semester.

(5) The score on the *American Chemical Society-National Science Teachers Association Cooperative Examination in High School Chemistry, Form 1961, Advanced Version*, given as a post-test during the final week.
6) The score on the Raths-Claro Critical Thinking Appraisal, Form YM, given as a post-test during the final week.

7) The score on the Hand Scale of Attitudes Toward College Courses: A Scale to Study Attitudes Toward College Courses, given as a post-test during the final week.

In order to clearly present detailed procedure plans, supplementary information has been placed in the appendix: Page 121 describes how the available periods were utilized. Page 122 presents a brief course outline. The two methods are compared for differences and similarities on pages 125 and 126. A period-by-period description of activities in both classes is given on pages 125-129. Pages 130-134 contain a detailed sample "part", while on page 135 may be found a description of the note-test system by Trahanovsky (23).

Procedures for Treating Data

Analysis of covariance was the primary statistical method for analyzing the data. This is a system of analysis which makes statistical control of experimental variables possible when it is not feasible to experimentally control the subjects (10, p. 74; 11, p. 317; 14, p. 362; 28, p. 578).

In comparing the covariance method with the matched pair procedure, McNemar stated:

The use of the covariance adjustment technique is far superior to attempts at pairing individuals from the intact group on the basis of one or more uncontrollable variables, a procedure which inevitably leads to a reduction of sample size and also runs astride a regression difficulty (14, p. 373).
For purposes of this study, the following data obtained for each student were used as control variables:

1. The ACT composite score, as given on the ACT card of each student, was obtained from the Office of Dean of Students. This control variable was designated as $X_1$.

2. The pre-test score on the Watson-Glaser Critical Thinking Appraisal, Form X1, was the control variable designated as $X_2$.

3. The pre-test score on the ACS-NSTA Cooperative Examination in High School Chemistry, Form 1963, Advanced Version, was the control variable designated as $X_3$.

The following were used as final criterion scores:

1. The total score of each student on the 50-item and three 40-item multiple-choice examinations was designated as $Y_1$.

2. The score, as a post-test score on the ACS-NSTA Cooperative Examination in High School Chemistry, Form 1963, Advanced Version, was designated as $Y_2$.

3. The score, as a post-test score on the Watson-Glaser Critical Thinking Appraisal, Form X1, was designated as $Y_3$.

4. The score, as a post-score, on the Ward Scale of Attitudes Toward College Courses: A Scale to Study Attitudes Toward College Courses was designated as $Y_4$. 
With respect to $Y_1$, $Y_2$, and $Y_3$ described above, a student was categorized in the top third in student ability if his predicted criterion score was in the top third of all scores of the two classes. Similarly, a student was categorized in the bottom third in student ability if his predicted criterion score was in the bottom third of all scores of the two classes.

These predicted scores were obtained by means of standard correlation and multiple regression analysis. Thus, there was a top third and a bottom third in student ability for $Y_1$, $Y_2$, and $Y_3$.

It was not possible to develop a regression equation for predicting students' scores on the Hand Scale of Attitudes Toward College Courses: A Scale to Study Attitudes Toward College Courses, since scores on the attitude scale showed very little correlation with scores on other variables used as covariates.

The Computer Center at Southeastern State College was utilized in the analyses of data, the 0.05 level of significance being used as the basis for acceptance of rejection of the null hypotheses.

Means and standard deviations for all sets of scores were determined both through a computer program and by means of a Marchant Deol-Magic calculator, Model SK. Comparative $t$-tests of all group means were also made by both the computer and the desk calculator.
A table representing the matrix of intercorrelations among the variables was prepared. These correlations played a vital role in determining the regression equations.

Three regression equations which enabled the prediction of \( Y_1, Y_2, \) and \( Y_3 \) scores were then developed in a manner described by McNemar (14, pp. 171-180). It was found that two of the independent variables, as covariates, were sufficient to use in each of the three regression equations developed. These covariates were the ACT composite scores and the Human-Think Critical Thinking Instrument scores. The use of the third covariate, the ACT-EXAM Cooperative Examination, was not justified mathematically (5, p. 400; 4, p. 434).

Although it was not necessary to determine adjusted means in the data analyses, as explained in Chapter III, many of the adjusted means were computed to increase the clarity of presentation and they will be listed at appropriate points throughout Chapter III, Collection and Treatment of Data. The mean adjustments were computed according to instructions in Statistical Methods in Educational and Psychological Research (26, pp. 348-361). Other sources of information relative to adjustment of means in analysis include Psychological Statistics (14, pp. 362-363), Design and Analysis of Experiments in Psychology and Education (11, pp. 521-525), and Statistical Principles in Experimental Design (28, pp. 619-621).

In order to test the hypotheses, students were placed in three ability levels according to their predicted criterion
scores \( (Y_1, Y_2, Y_3) \) and the data were then subjected to the analysis of covariance by level and by group. Instructions for this analysis of covariance are presented by Wert, Weidt, and Ahmann (26, pp. 343-363).

In the analysis of covariance by method and by level, it was necessary to obtain the deviation form sums of squares and crossproducts for all sources of variation (26, p. 353). These obtained through a computer program developed especially for this study by a fellow associate who is a physics professor in the Department of Physical Sciences at Southeastern State College. As with all other calculations made in connection with the study, results of the program were checked with a Marchant Deci-Magic desk calculator. All comparisons, except comparisons of attitudes of students toward the chemistry course, were made by both \( t \) tests and by the analysis of covariance. Prior to the experiment, the analysis of covariance technique was selected as the primary method of analysis, since there was at that time no assurance that the groups would compare favorably and satisfactorily with respect to variables believed to represent important abilities related to the potential for success in achievement and critical thinking. Had it been known prior to the experiment that the two groups would compare favorably with respect to critical variables, with no significant differences
as was actually the case, the $t$ test method of comparisons would perhaps have been sufficient and satisfactory.

Although this short discussion concerning procedures for treating data has presented only a brief description of the procedures, a more detailed discussion of the steps involved is given in Chapter III.
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CHAPTER II

SURVEY OF RELATED LITERATURE

Introduction

Chapter II is divided into the following three sub-topics: (1) literature related to independent study, (2) literature related to the study of attitudes, and (3) literature related to critical thinking. Only those studies which appeared to be pertinent to the current study are presented, and no attempt was made to review all the literature related to the topics.

Literature Related to Independent Study

Due to the vast amount of new material which is rapidly making its appearance in the field of chemistry, a serious problem of proper coverage is becoming more acute. Obviously, all material useful in a student’s education cannot be pursued in lecture periods. Therefore, it is becoming urgent that students, as well as teachers, come to a realization that a reasonable amount of time outside of class must be spent in the educational process. Concerning the necessity for out-of-class study, Schwab contended:

The teacher whose past training involved passivity and dependence and who tends to demand the same of his students,
will need, in addition, to discover the possibilities of self-education—not only for himself but for his students. There are two reasons for this suggestion. First, self instruction is the only practicable solution to the problem of "coverage." The problem of finding enough time to "cover" what we wish to cover is not and, for years, has not been a problem of finding enough student time. It has been a problem of finding enough classroom time and enough teacher time to "cover," in the conventional way, within the conventional framework of the school day, on the assumption that all "coverage" must be coverage in the classroom. I now suggest that a substantial part of "coverage" be "covered" by the student on his own (53, p. 9).

Less time available for presentation by the instructor entailed the necessity of more independent study by the students, and since the note-test system of teaching demanded much less lecturing and more independent study, it seemed pertinent to the study to examine the literature in an effort to determine the probable effects of these two changes of emphasis. This examination was done prior to the experiment with the result that very little helpful recent information concerning the effects of the two altered factors was obtained within the subject area of science, but a number of studies dealing with these effects in other fields revealed little difference in results.

Since the note-test system of teaching involved less teacher presentation of material, it was necessary to determine if the reduced lecture time might have undesirable effects on the students of the experimental group. Ramsey and Howe (48) have presented the following evidence related to this concern:
The length of time a teacher spends teaching a given content unit has surprisingly little effect on the achievement of content outcomes of the students. Whether its effects on other outcomes is not known, nor are the factors known which determine how long a teacher spends teaching a particular unit (48, p. 79).

Further support of this contention was reported by Hardy (22) in his examination of CHEM Study students with students in traditional chemistry classes. He wrote,

"... it should be noted that there were no significant correlations between student achievement and time spent in classroom lecture, discussion, or in laboratory work" (22, p. 99).

According to Nokert and Neal (14), little recent information has been reported concerning the effectiveness of lecture and discussion methods. They wrote, "Thus Le ton (1961), in a limited comparison of lecture and group discussion in a course in child development, found no differences that could be ascribed to the procedures used" (14, p. 309).

With respect to independent study,

Antioch's carefully executed appraisal of independent study, reported by Churchill (1961), showed that students in seven first-level general education courses who spent approximately one half of the usual class time in independent study or small group meetings did as well and were as satisfied with the instructors and courses involved as were those who attended classes regularly. But all three methods produced little gain in "learning resourcefulness" or the achievement of skills and attitudes favoring continued independent study (14, p. 309).

Ulrich and Pray (56), in their comparison of directed self-study with lecture in teaching general psychology, concluded that
the amount of lecture time to which students were exposed made little difference in their achievement scores on a final multiple-choice examination. Their subjects consisted of 61 students who were enrolled in three sections of general psychology at Illinois Wesleyan University. The three classes consisted of 22, 22, and 17 students respectively, and a student was in a specific class solely because he registered for that particular section.

At the University of South Florida, Hartnett and Stewart (24) compared final examination grades of students in independent study with those of students taught by traditional methods. Six subject matter areas were involved and the students in traditional methods classes were matched with students who attended no classes, but took the same course by independent study. The minimum number of matched pairs for each subject matter area was 15 and, for the most part, they were matched exactly on the basis of composite percentiles obtained by administering the Florida Twelfth Grade Test battery, a series of tests used for admission purposes by state universities in Florida. They reported, "The findings revealed significant differences favoring the independent study group in 2 of the 6 courses, with the other courses indicating no significant differences between the groups" (24, p. 356). It was interesting to note that in every case, the mean performance of the independent study students was higher, but significantly so only in two of the six groups.
In a Psychology of Child Development course, Parsons (46) compared kinescope-correspondence study without an instructor, conventional classroom discussion with an instructor, and independent correspondence study. He found no significant differences in achievement at the end of the course; however, four months after conclusion of the course, there was a significant difference at the 0.05 level favoring the correspondence group over the classroom group.

In addition to measuring achievement, Parsons was concerned with the students' preferences for instructional methods, and it was determined that

... students' preferences for their own instructional treatments tend to start low and increase through time under the unfamiliar correspondence method, whereas they tend to decrease with time for the partly familiar kinescope method and remain uniformly high under the customary classroom method (46, p. 40).

Lewis (36), in his study of three methods of presenting one segment of Elementary Political Science, found that the freshman group which received no lectures and held no discussion meetings, but were issued a specially prepared study program, scored significantly higher on the criterion measure of achievement than the freshman group which received lectures over the assigned and related material. The achievement of the freshman group which received no lectures or no study program fell between that of the lecture and study program groups.

In an experimental comparison of an independent study situation with a regular classroom situation in the area of
Science Education, Combs (10) reported no significant difference in scores by students on the Watson-Glaser Critical Thinking Appraisal, Test on Understanding Science, and the Minnesota Teacher Attitude Inventory.

Celinski (9) described an approach to teaching, which he referred to as a "radical" approach to teaching. The approach appeared to have some of the same characteristics as the note-test approach to teaching. The activity around which his approach centered was "announced repetitive tests." In this system, he attempted to reverse the flow of information so that it went from student to teacher instead of from teacher to student. The flow of information was utilized by the teacher for guiding the students' activities. In Celinski's system, "Lectures, and the accompanying ceiling on student achievement, have been virtually eliminated by engaging the student in critical and independent studies directly from the information sources" (9, p. 110).

One of the most extensive resumes of independent study was made by Capretta (8) who pointed out the following important findings by other investigators: (1) Desirable attitudinal changes are likely to accompany independent study methods, (2) it is not necessary that independent study methods be used exclusively for the superior or advanced student, and (3) there is evidence that independent study may foster the development of critical thinking ability with little or no loss in learning factual information. Thus, excellent evidence was presented
which justified independent study as a means of achieving the important goals of desirable student attitudes, critical thinking ability, and gaining factual information.

Concerning independent study in a college social science setting, Brown and Adams (?) reported that

The social science instructors developed an interest in this program for a number of reasons. They believed that students who are active in the learning processes become more adept at critical thinking. They further felt that these students develop greater self-reliance and that such study tends to stimulate them to greater achievement (7, p. 29).

According to Baskin,

There are several new elements in the way independent study is now being employed in a number of institutions: (1) as an experience common to all students rather than the superior or able student only; (2) at the very beginning of the student's college career, i.e., the freshman year, as contrasted with the usual practice of reserving these experiences for the senior or upper-division years only; and (3) the incorporation of procedures which make use of new media and technology (programmed texts, single-concept films, playback of video tapes, etc.) in connection with the student's independent studies (2, p. 320).

Extensive utilization of independent study methods at Antioch College over a four-year period was reported by Baskin. He pointed out that "attitudinal factors might be as important in learning by these methods as individual ability" (l, p. 164). His report helped to strengthen the belief that students other than the superior profit from independent study, also, that the method may be used in beginning as well as advanced classes.

Support for Baskin's contention came from a study by Bigelow and Egbert at Brigham Young University during the 1965 spring semester. They wrote, "The implication here seems to
be that the better adjusted, more secure students perform more successfully in independent study than do others" (3, p. 39). Also, "No significant personality differences appeared between successful students in traditional and independent study" (3, p. 38). The foregoing remarks imply that student adjustment and personality factors are of more concern than intellectual factors in determining the probability of a student's success in independent study.

It appeared, from a report by Mitterling (42), that special tutoring of students in independent study methods might increase the chances of success. At Colorado College, "a number of students had trouble getting started, but by the beginning of the second semester almost all had gained momentum" (42, p. 471). Since some of those students, who were highly selective, had trouble getting started, it is likely that students in other settings might also have trouble.

Further confirmation that independent study programs may be useful for poorer students was reported by Waggoner. Concerning the independent study programs at the University of Kansas, some students offered this opinion: "Many believed that even mediocre students would profit from similar programs, and suggested that honors programs should be open to any who wished to undertake them" (57, p. 406).

If independent study methods are administered properly, it is unlikely that they will have detrimental effects on students who pursue studies in this manner. Lending support to this, McKeachie presented the following:
With the support of the Fund for the Advancement of Education, a number of colleges have recently experimented with more elaborate programs of independent study. As with other comparisons of teaching methods, few differences have been found between achievement of students working independently and those taught in conventional classes (38, p. 1146).

In the present study, much of the time which the experimental group of students spent in independent study was utilized in answering assigned questions to be handed in prior to discussion of the related material in class. Thus, a considerable amount of direction was given to the students in the form of these assignments. According to Marshall and Burkman, "... the best approach to teaching any subject (particularly science) is through carefully phrased and sequenced questions built into the instructional materials used" (40, p. 7).

From the independent study programs discussed in this section, it may be perceived that one should have little fear that students will suffer as a result of increased independent study accompanied by a decrease in lecture time by an instructor. In the present study, more independent study by the experimental group of students than by the control group was mandatory since less class time for instructional or expository purposes was available.

Literature Related to the Study of Attitudes

Numerous definitions of attitude appear in the literature. A thorough study of the nature of attitudes was made by Bradberry (5), who stated several definitions of attitude by various authors.
The definition which appeared to serve Bradberry's purposes best was one by Klausmeier and Goodwin, as follows: "... attitudes are learned, emotionally toned predispositions to react in a consistent way, favorable or unfavorable, toward a person, object, or idea" (34, p. 24).

Rhine (50), who wrote of the relationship between concept-formation and attitude acquisition, likewise mentioned the many definitions of attitude. He stated that "Nelson's review of the literature disclosed 23 mor or less different definitions of attitude ..." (50, p. 362).

In utilizing the concept-formation interpretation, he defined a concept by stating that "... a concept is considered a mental principle through which an individual can classify a number of objects in his stimulus world" (50, p. 362). He clearly conveyed his belief in the close relationship between concept-formation and attitudes by the following statement: "A concept formation approach to attitude learning also enables any systematic viewpoint which can account for concept-formation to account at the same time for attitude formation" (50, p. 362).

In the preface of Basic Concepts of Teaching, Woodruff disclosed pertinent information based on a writing by Gagné and Bolles (19):

It is generally agreed among serious students of learning and behavior that such things as attitudes are not primary elements in learning. They are by-products. Learning is not basically a process of attitudinal change. It is a process of change in
concepts, motor abilities, values, habits, and symbolism. When these things change, they produce changes in the behavioral manifestations which we call attitudes, appreciations, loyalties, and so on" (60, p. vii).

Lending support to the contention that attitude changes are closely allied to concept-formation was a study by Miller and Biggs (41) cited by Woodruff (60) in Basic Concepts of Teaching. They found that verbal discussion was capable of producing attitude changes of boys in third-year secondary school classes if the verbal discussion resulted in altering concepts.

Another study reported by Woodruff (60) was a study of the relationships among values, concepts, and attitudes. The study was conducted by Woodruff and DiVesta (61), with 84 beginning psychology students as subjects. Instruments were utilized which measured changes in values, concepts, and attitudes toward sororities and fraternities. Three important findings were reported:

1. Changes in concepts were accompanied by predicted changes in attitudes.
2. Attitudes of any strength were found only when a subject's highest values were involved in the subject of the attitudes, and when the individual possessed meaningful concepts about the subject.
3. There is a high positive correlation between a weighted score made up of one's highest positive values, and his concepts of a given object combined, and a score taken from an attitude test in which the same object is the subject (60, p. 103).

Woodruff further remarked,

This study provides the first clear evidence that knowledge plays a direct and important role in the determination of attitudes, by showing that one's behavior tends to follow a line which the individual believes will foster the things he cherishes most highly, and that when his beliefs change his behavior will change.
accordingly. Hence education which is intended to affect behavior and attitudes should probably make its attack on the conceptual patterns of individuals, by introducing meaningful information in a way which provides the student with understanding and which makes application to one's daily choices clear (60, p. 103).

The measurement of attitude changes comprised one aspect of a study conducted by Popham and Sadnavitch (47). One part of the experiment consisted of an evaluation of filmed chemistry courses in twelve public secondary schools in southeast Kansas. The subjects included all students enrolled in chemistry during the 1959-1960 school year. The attitudes of both the experimental (film group) and the control (non-film group) classes declined, but it was found that the attitude decline of the experimental group was to a greater extent than the attitude decline of the control group. This difference in decline was significant beyond the 0.05 level.

The preceding information constitutes ample evidence to corroborate the fact that attitudes are subject to rapid measureable change. According to Combs, "... attitudes do seem to be subject to rapid modification and change" (10, p. 72).

Although it has been shown that attitudes may be altered rapidly, it has been difficult to obtain correlations between attitudes or attitude-changes and other variables. Thus, in a general psychology class, Wofford and Willoughby (59) found significant relationships between course grades and attitudes toward the course. On the other hand, Neale, Gill and Tismer (44) found very little relationship among sixth-graders between
school achievement and attitudes toward school subjects. They stated, "Despite a widely-held belief that favorable attitudes toward school and school subjects contribute to learning, no substantial body of empirical knowledge has been developed to document such a belief" (44, p. 233). In their study, attitudes toward school subjects were of no assistance in predicting school achievement. The results led to the conclusion that attitudes toward school subjects may play only a limited role in school achievement.

Presently, a fruitful source for investigation appears to be the effect of independent study methods on student attitudes. The setting for one such recent investigation was a large southern California suburban high school. High school biology students were divided into the following four group categories: (1) independent study, (2) small-group discussion, (3) large-group discussion, and (4) a mixture of independent study, small-group discussion, and large-group instruction. The function of the teacher in the independent study group was to act only as a resource person. The following results were reported:

No significant difference in achievement was found among the groups at the 1 or 5% levels of confidence using analysis of covariance (the pretest was used as the covariate to the posttest). However, a student questionnaire administered at the close of the experiment disclosed a substantially higher attitude toward the experiment by students in independent study (29, p. 115).

According to Baskin, "Student-centered methods of learning, including various methods of independent study, tend to produce
greater gains in insight and problem-solving capacities and to promote more attitudinal changes than comparable 'instructor-centered' methods." (2, p. 320).

Four hundred seven introductory college chemistry students constituted the subjects for Myers' (43) investigation of the relationship between students' attitudes toward science and scientists and pertinent variables. The students' attitudes were not favorably changed during the progress of the chemistry course, but declined instead. There were significant correlations between post-attitude scores and the final examination grade and course grade. Also significant was the correlation between the final grade and the pre-attitude score. The instrument for measuring attitudes was developed by Myers.

Boeck (4) utilized eight ninth-grade science teachers and sixteen classes in an experiment conducted at St. Paul, Minnesota. A unit on mirrors and mirror-images was selected to provide the subject matter content for the experiment and the following teaching methods were employed: (1) reading about mirrors and mirror-images, along with discussion; (2) presentation by demonstrations, diagrams, and concrete illustrations and (3) a combination of the two preceding methods. He reported no significant difference between methods in a 50-item multiple choice achievement examination or on a 32-item non-verbal performance test. He further reported that "the only variable showing a large difference in this respect was the attitude
solae, where the reading material method of instruction was clearly regarded with least favor" (4, p. 94).

Feldhusen demonstrated, in a class of 55 introductory psychology students, that frequent quizzing and post-mortem discussion of tests produced positive desirable effects on student perceptions. In summarizing the results, he stated:

The results of this study indicate that student perceptions of the frequent quizzes are highly favorable. They reported that the quizzes helped them learn more, motivated them to study, and helped them check on their progress or learning. In short, they welcomed the more frequent test regimen.

The post-mortem discussion of quiz performance or results were perceived less favorably. The majority of the students felt that the discussions did not improve subsequent test performance, but a slight majority felt that the discussion helped in preparation for the final examination. One highly favorable aspect of the post-mortem discussions was the value students reported in learning to avoid foolish and technical errors. Three-fourths of the students reported this advantage (17, p. 53).

In a study by Turney (55), a class of 40 psychology students comprised the experimental group and a class of 25 psychology students comprised the control group. The experimental section was given 12 short quizzes at intervals throughout the semester in addition to a mid-term and final examination. The control group was given only one short examination in addition to the mid-term and final examination. Significant differences in achievement were obtained, the experimental group being the better achievers. The following statement concerning the experiment was noteworthy: "It is also significant to note the excellent attitude of the experimental section toward frequent testing" (55, p. 762).
At Purdue University, frequent short quizzes, in addition to regular monthly quizzes, were administered to 198 students in an experimental Government 10 class in an effort to determine whether they would result in steadier application of the students to the task at hand. The control class of 97 students was given only the regular monthly quizzes. A poll of the students in both classes showed that the practice of weekly quizzes was favored over less frequent quizzes. During the semester, voluntary weekly discussion groups were provided for both classes. The consensus was that

We may conclude that, barring systematic effects that could bring about this result from variables not controlled in this study, the experimental frequent-quizzing method did bring about significantly greater achievement on the part of those students to whom it was applied (18, p. 12).

In their excellent analysis of research on instructional procedures in secondary school science, Ramsey and Howe (49, p. 66) cited two pertinent studies related to attitude change. Davis (12) attempted to produce a change in attitude toward race and fallout. He found that student attitudes could be changed through instructional procedures and that intelligence level was immaterial in producing those changes. Also reported by Ramsey and Howe (49, p. 66) was a study by Kahn (30) who found that reading level was not an important factor in producing significant changes in attitude. In his class, he utilized current events as a basis for teaching attitudes.
One of the ten conclusions of Ramsey and Howe was that "a desirable attitude change can be taught by carefully designed instructional procedures; this applies to all ability groups" (49, p. 68).

A recent book by Mager (39) contained the following statement on the inside front cover: "If I do little else, I want to send my students away with at least as much interest in the subjects I teach as they had when they arrived." This statement, it seems, echoes the sentiments of the vast majority of teachers today. However, it appeared, from a study of the literature, that this goal was being accomplished in far too few cases.

Literature Related To Critical Thinking

One of the most important goals in education is the development of the ability to do critical thinking. Many studies have been focused on this aspect of learning, but methods used for the improvement of critical thinking have produced inconsistent results.

Edwards stated that it appears that ability to do critical thinking is a valid objective of the schools in that it is possible to isolate techniques of critical thinking and test for the acquisition of skill in the use of these techniques (15, p. 271).

Watson and Glaser developed one of the most widely used instruments for the purpose of determining critical thinking ability. They stated:
In developing the Critical Thinking Appraisal, the authors have viewed critical thinking as a composite of attitudes, knowledge, and skills. This composite includes: (1) attitudes of inquiry that involve an ability to recognize the existence of problems and an acceptance of the general need for evidence in support of what is asserted to be true; (2) knowledge of the nature of valid inferences, abstractions and generalizations in which the weight or accuracy of different kinds of evidence are logically determined; and (3) skills in employing the above attitudes and knowledge (58, p. 10).

Other than the viewpoint presented by Watson and Glaser, many other definitions and characteristics of critical thinking have been delineated. In fact, Watson and Glaser have reprinted in their Manual (58) a list of five critical thinking abilities which were proposed by the Cooperative Study of Evaluation in General Education (13). This list, however, was similar to the Watson and Glaser composite given above.

Good alternately defined critical thinking as "thinking that proceeds on the basis of careful evaluation of premises and evidence and comes to conclusions cautiously through the consideration of all pertinent factors" (21, p. 570).

Ennis, in his thorough study of critical thinking, listed the following twelve aspects of critical thinking:

1. Grasping the meaning of a statement.
2. Judging whether there is ambiguity in a line of reasoning.
3. Judging whether certain statements contradict each other.
4. Judging whether a statement is specific enough.
5. Judging whether a conclusion follows necessarily.
6. Judging whether a statement is actually the application of a certain principle.
7. Judging whether an observation statement is reliable.
8. Judging whether an inductive conclusion is warranted.
9. Judging whether the problem has been identified.
10. Judging whether something is an assumption.
11. Judging whether a definition is adequate.
12. Judging whether a statement made by an alleged authority is acceptable (16, p. 84).

A number of possible causes of the failure of various methods to improve critical thinking ability have been offered. According to Edwards (15), a lack of suitable measuring devices coupled with slow improvement in thinking ability has been partially responsible. Marshall and Burkman have substantiated this feeling by writing that

no present day testing expert has stated with much confidence how one goes about devising a test to measure critical thinking. Unfortunately, terms such as critical thinking are often defined in terms of "that which a certain test measures" (40, p. 103).

Yet Hill, in his evaluation of the Watson-Glaser Critical Thinking Appraisal, has stated that "the five subtests which have been retained are clearly pertinent to most definitions of critical thinking" (26, p. 796). Further, concerning the appraisal of critical thinking, Hill related that "... the Watson-Glaser Critical Thinking Appraisal is one of the useful instruments for this purpose" (26, p. 797).

Hovland's evaluation of the Watson-Glaser Critical Thinking Appraisal was similar to that of Hill as he wrote, "The Watson-Glaser test is a conscientious imaginative effort to provide appraisal in a most difficult area—that of 'critical thinking'" (28, p. 797).
One of the most enthusiastic analyses of the Watson-Glaser Critical Thinking Appraisal was that by Helmstadter. He lauded the test-makers for their reports concerned with test standardization, reliability, and validity. Although admitting there may be some flaws in the test, he stated that "... the Watson-Glaser Critical Thinking Appraisal represents a highly professional attempt to measure an important characteristic" (25, p. 256).

Buane (52) classified the Watson-Glaser Critical Thinking Appraisal as one of the better testing instruments, while Troxel and Snider issued the following statement concerning the Test on Understanding Science, the Watson-Glaser Critical Thinking Appraisal, and the ACS Cooperative Examination in General Chemistry, Form 1963:

Certainly, all teachers do not have as all of the objectives in the science courses they teach what these examinations measure. For those who do have at least some of the objectives, as well as for professional researchers in science education, these examinations may be valuable assets (54, p. 76).

Although the ability to think has often been a goal in science education, there have been very few specific conscious attempts to increase the thinking ability of students (11, p. 9).

Hollenbach and DeGraaf attested that the development of better abilities and habits of thinking is a part of the responsibility of every college teacher, perhaps more important in some courses than in others, but never completely absent from any course (27, p. 128).
They offered eight conclusions for the improvement of instruction, and each of these conclusions pointed out a deficiency in most of the existing educational systems. Most of the deficiencies pointed out were those which could be alleviated by the teachers through the alteration of present teaching methods.

Confidence in the ability to train teachers how to teach critical thinking was expressed by O'Neill (45), and this appeared to be an excellent follow-up of the Hope College endeavor. These two studies at least voiced the opinion that in order to succeed in teaching critical thinking, special efforts must be made in that direction.

Ramsey and Howe (49, p. 65) cited an experiment by Kazstrinos (31, 32) in which a critical thinking method of teaching was utilized in teaching high school biology students. The method did produce, in one semester, significant changes in the ability of students to think critically. According to George, "certain studies have indicated that critical-thinking abilities can be and are improved when the teacher makes a special effort to emphasize these abilities" (20, p. 12).

A convincing experiment conducted by Rickert provided further evidence that critical thinking abilities can be significantly changed in one semester. He hypothesized that "the ability to think critically is improved significantly by a physical science course that gives students opportunities
to analyze problems, examine assumptions, collect and organize data, and test hypotheses" (51, p. 27). The subjects were 22 students in each of three classes and the three classes were taught by three different methods: (1) physics taught in a traditional manner, (2) a survey physical science course taught in a traditional manner, and (3) a third physical science course taught in what was called an eclectic manner in which students were given ample opportunities to analyze problems, examine assumptions, collect and organize data, and test hypotheses. The instrument used was the A.C.E. Test of Critical Thinking, Form G. The eclectic group surpassed both the physics group and the survey physical science group at the .05 and .01 levels respectively. Concerning the investigation, Rickert related that

the experimental data supports the hypothesis that the ability to think critically can be improved in the short span of one semester by a course that gives students opportunities to analyze problems, examine assumptions, collect and organize data, and test hypotheses (51, p. 27).

Even though some of the above studies have indicated the possibility of significantly increasing critical thinking ability with special efforts, many other experiments have failed to produce significant changes in this respect. Lee (35), in utilizing 165 high school chemistry students in six classes, compared the increase in critical thinking ability of students taught in a conventional manner with the increase in critical thinking ability of students taught by a problem-solving method. He found no significant difference in change
of critical thinking ability due to method when the experimental group as a whole was compared with the control group as a whole. However, the lower ability students of the experimental group exceeded low ability students of the control group at the .10 level of significance. In a subjective evaluation, Lee concluded that the experimental group exceeded the control group in motivation, self-discovery, and enthusiasm.

The effects of independent study were investigated by Combs (10) in his experiment involving science education students. He randomly assigned 37 and 38 students to the independent study and regular classroom groups respectively. Both groups showed a slight decline in scores on the Watson-Glaser Critical Thinking Appraisal, but there was no significant difference in the decline due to method.

Hardy (23) utilized the Watson-Glaser Critical Thinking Appraisal in his comparison of CHEM Study students (n=104) with traditionally taught chemistry students (n=104). Although the CHEM Study students scored higher than traditionally taught students on the critical thinking criterion, the difference was not significant. Thus he concluded that "chemistry students taught by the CHEM Study approach do not differ significantly from the students of traditional chemistry in level of general critical thinking" (23, p. 275). Other interesting information from Hardy's study was that age was found not to be significantly related to level of critical thinking (22, p. 95).
Another study which further emphasized the difficulty of increasing students' abilities in critical thinking was conducted by Lyle (37). The instrument used was *A Test of Critical Thinking, Form G*, which was developed by the American Council on Education Cooperative Studies of Evaluation in General Education. The 55 subjects were college general psychology students, approximately half of which were in the control group. The experimental group was taught by a method in which "... as many procedures as possible were utilized which have been purported to be effective in stimulating critical thought" (37, p. 129). The two groups had almost identical mean scores on the *Test of Critical Thinking, Form G*, administered as a pre-test, and both groups showed almost equivalent gains on the test, administered as a post-test. Therefore, the difference in gain in mean scores was far from significant.

Chemistry students numbering 153 and non-chemistry students numbering 149 were randomly selected to participate in a study by Brown (6) in which critical thinking abilities and attitudes toward science were compared. The Cornell Critical Thinking Test, Form X was administered to the subjects in a pre-test post-test design. Although chemistry students outgained the non-chemistry students in critical thinking ability, the differences were not significant.

An interesting factor which may merit consideration in attempts to increase critical thinking ability is the extent of dogmatism of the subjects involved. Kemp (33) showed that
open-minded college students tended to excel in criteria involving critical thinking. His conclusion was:

The low dogmatics are more successful than the high in critical thinking. The high dogmatics have the greater percentage of errors in those problems which require the study of several factors or criteria for decision and the deferring of a conclusion until each factor has been judiciously considered (33, p. 318).
CHAPTER BIBLIOGRAPHY


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55. Turney, Austin H., "The Effect of Frequent Short Objective Tests Upon the Achievement of College Students in Educational Psychology," School and Society, XXXIII (June, 1931), 760-762.


CHAPTER III

COLLECTION AND TREATMENT OF DATA

In order to utilize the analysis of covariance technique, it was necessary to select variables which possessed some potential for predicting outcomes of achievement and critical thinking ability. The following scores for each student in both groups were obtained prior to the beginning of instruction: (1) the pre-test score on the Watson-Glaser Critical Thinking Appraisal, Form YM, (2) the pre-test score on the ACS-NSTA Cooperative Examination in High School Chemistry, Form 1963, Advanced Version, (3) the ACT composite score. Tables I and II present these scores, along with other scores which were used in the analyses. Table I presents the scores of the control group, while Table II presents the scores of the experimental group.

In addition to the above scores, the following additional scores of each student are shown in the tables: (1) the post-test score on the ACS-NSTA Cooperative Examination in High School Chemistry, Form 1963, Advanced Version, (2) the post-test score on the Watson-Glaser Critical Thinking Appraisal, Form YM, (3) the total score attained on four teacher-constructed multiple-choice examinations (maximum total score = 170 points).
### TABLE I

**Scores of the Control Group on All Variables Used in Analyses**

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<tr>
<th>Stud. No.</th>
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<th>ACSPR</th>
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## TABLE II

**Scores of the Experimental Group on All Variables Used in Analyses**

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and (4) the score on the Hand Scale of Attitudes Toward College Courses: A Scale to Study Attitudes Toward College Courses.

Table III gives the arithmetic means and standard deviations of each group and of the combined groups for the variables utilized in the experiment. Arithmetic means were calculated by the formula, \( M = \frac{\Sigma X}{N} \), where \( M \) = the arithmetic mean, \( \Sigma X \) = the sum of scores made on a variable by an entire group, and \( N \) = the number of students involved in the scoring (5, p. 16).

Standard deviations were calculated by the formula, \( S = \frac{1}{N} \sqrt{\frac{\Sigma X^2}{N} - \left( \frac{\Sigma X}{N} \right)^2} \), where \( S \) = the standard deviation, \( N \) = the number of students involved in the scoring, \( \Sigma X^2 \) = the sum of the squares of each score, and \( (\Sigma X)^2 \) = the square of the sum of all scores made by a group (5, p. 23).

Careful examination of Table III revealed the following features: All variables, except the HSA scores, were quite comparable for the two groups. The control group showed a slight increase on the Watson-Glaser Critical Thinking Appraisal from pre-test to post-test while the experimental group showed a slight decline. This decline was unexpected, although not unusual in experimental investigations of teaching methods (2, 3).

Information from Table III also showed that the experimental group scored slightly higher on both the MCTOT and ACSPT criteria, in spite of the fact that ACT and WGPR arithmetic means were slightly less for this group.
### TABLE III

ARITHMETIC MEANS AND STANDARD DEVIATIONS OF ALL VARIABLES USED IN THE ANALYSES

<table>
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<th>Variable</th>
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The large comparative difference in scores of the two groups was that of the HSA. The experimental group showed better attitudes, by far, toward the chemistry course at the end of the semester than did the control group.

In order to determine if both groups were representative of the same population at the beginning of the semester, *t*-test ratios on each of the proposed predictive variables were determined.
The formula used in these comparisons was presented in
Elementary Statistical Methods in Psychology and Education
(1, p. 348) and was as follows:

$$t = \frac{M_1 - M_2}{\sqrt{\left(\frac{N_1 S_1^2 + N_2 S_2^2}{N_1 + N_2 - 2}\right) \left(\frac{1}{N_1} + \frac{1}{N_2}\right)}}$$

Symbols in the above formula have the following meanings:

- $M_1$ = arithmetic mean of scores of Group 1.
- $M_2$ = arithmetic mean of scores of Group 2.
- $N_1$ = number of scores of Group 1.
- $N_2$ = number of scores of Group 2.
- $S_1$ = standard deviation of scores of Group 1.
- $S_2$ = standard deviation of scores of Group 2.

Information obtained from the t-test comparisons of the
independent variables is presented in Table IV. The table
shows that the groups were, at the beginning of the experiment,
representative of the same population in so far as the three
proposed predictive variables were concerned.
**TABLE IV**

**t-TEST COMPARISONS OF THE PROPOSED PREDICTIVE VARIABLES**

<table>
<thead>
<tr>
<th>Variable Tested</th>
<th>t-Value</th>
<th>df</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACT Control with Experimental</td>
<td>0.892</td>
<td>51</td>
<td>NS*</td>
</tr>
<tr>
<td>WGPR Control with Experimental</td>
<td>1.284</td>
<td>51</td>
<td>NS</td>
</tr>
<tr>
<td>ACSPR Control with Experimental</td>
<td>-0.298</td>
<td>51</td>
<td>NS</td>
</tr>
</tbody>
</table>

* Not significant

Other t-test values of concern in the experiment are shown in Table V. In comparing pre-test scores with post-test scores of the same group, it was necessary to use a different formula than the formula given on Page 70. The formula used for this purpose was

\[
t = \frac{(M_1 - M_2) \sqrt{n}}{\sqrt{\frac{\Sigma d - (\Sigma d)^2}{n}}}
\]

where \(M_1\) = the arithmetic mean of the pre-test, \(M_2\) = the arithmetic mean of the post-test, \(n\) = the number of pairs of pre-test post-test scores, \(\Sigma d^2\) = the sum of the squares of
the differences in pre-test and post-test scores, and \((\Sigma d)^2 = \)
the sum of all the differences in pre-test and post-test
scores and this sum squared.

Based on the information presented in Table III, post-
test scores of the two groups as a whole were compared in Table V
by means of the \(t\)-test. Justification for this comparison on
the basis of \(t\) values stems from the almost negligible differences
of the two groups at the beginning of the experiment in so far
as the predictive variables were concerned. As Table IV
indicated, none of the \(t\)-tests of the control variables at the
beginning of the semester showed any significant difference
in the two groups; however, in both the ACT and WGPR comparisons,
the control group showed a slight superiority.

There was very little difference between groups in MCTOT
scores, the \(t\)-test yielding a value of 0.074 in favor of the
experimental group.

In the ACSPT examination, the \(t\)-test yielded a greater
value, 0.505, in favor of the experimental group, but this
value was far from significant.

The examining committee suggested that since no pre-
attitude inventory was given, it would not be experimentally
sound to conclude that a difference in attitudes of the two
groups toward the course at the end of the semester would be
due to a difference in teaching methods. The suggestion proved
to be valid since there was little or no correlation of the HSA
with any of the other variables.
### TABLE V

**t-VALUES INVOLVING THE FOUR CRITERIA USED IN THE ANALYSIS OF DATA**

<table>
<thead>
<tr>
<th>Variable Tested</th>
<th>t-Value</th>
<th>df</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>WGPR with WGPT, Control Group</td>
<td>-0.854</td>
<td>25</td>
<td>NS*</td>
</tr>
<tr>
<td>ACSPR with ACSPT, Control Group</td>
<td>-4.155</td>
<td>25</td>
<td>.001 level</td>
</tr>
<tr>
<td>WGPR with WGPT, Experimental Group</td>
<td>0.405</td>
<td>26</td>
<td>NS</td>
</tr>
<tr>
<td>ACSPR with ACSPT, Experimental Group</td>
<td>-4.592</td>
<td>26</td>
<td>.001 level</td>
</tr>
<tr>
<td>MCTOT, Control Group with Experimental Group</td>
<td>-0.074</td>
<td>51</td>
<td>NS</td>
</tr>
<tr>
<td>ACSPT Control Group with Experimental Group</td>
<td>-0.505</td>
<td>51</td>
<td>NS</td>
</tr>
<tr>
<td>WGPT, Control Group with Experimental Group</td>
<td>1.776</td>
<td>51</td>
<td>NS</td>
</tr>
<tr>
<td>HSA, Control Group with Experimental Group</td>
<td>-2.777</td>
<td>51</td>
<td>.01 level</td>
</tr>
</tbody>
</table>

* Not Significant

Because there was no significant difference in comparative scores of the two groups on three control variables tested at the semester's beginning, there was no reason to believe that a significant difference in initial attitudes of the two groups existed. If the assumption of no initial difference were accepted, it could be concluded that the experimental method...
of teaching resulted in significantly better attitudes of students toward the course than did the control method. A $t$-test value of $2.777$ in favor of the experimental group indicated significance at better than 0.01 level. Such a large difference in attitudes of the two groups merits continuing evaluation of both teaching methods.

A correlation matrix of inter-relationships among all variables was developed. The raw score formula, obtained from *Psychological Statistics* (5, p. 112) and programmed on computer cards for computation of the correlations, follows:

$$r = \frac{N \sum XY - \sum X \sum Y}{\sqrt{N \sum X^2 - (\sum X)^2} \sqrt{N \sum Y^2 - (\sum Y)^2}}$$

where $r$ was the Pearson product moment correlation coefficient, $N$ was the number of scores, $\sum XY$ represented the sum of the crossproducts of two variables, $\sum X \sum Y$ represented the total sum of one variable multiplied by the total sum of another variable, $\sum X^2$ and $\sum Y^2$ represented the sum of the squared raw scores of two variables respectively, while $(\sum X)^2$ and $(\sum Y)^2$ represented the sum of raw scores of each of two variables respectively and each of these two sums squared.

The correlation matrix of all variables is shown in Table VI. Use of the correlation matrix facilitated the determination of control variables to utilize in development of regression equations for the following three criteria: (1) MCTOT scores, (2) ACSPT scores, and (3) WGPT scores.
<table>
<thead>
<tr>
<th></th>
<th>ACSPR</th>
<th>WGPR</th>
<th>ACT</th>
<th>ACSPT</th>
<th>WGPT</th>
<th>HSA</th>
<th>MCTOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACSPR</td>
<td>1.00000</td>
<td>0.07285</td>
<td>0.09341</td>
<td>0.11265</td>
<td>0.03179</td>
<td>-0.08736</td>
<td>0.06696</td>
</tr>
<tr>
<td>WGPR</td>
<td>0.07285</td>
<td>1.00000</td>
<td>0.69379</td>
<td>0.54494</td>
<td>0.76331</td>
<td>-0.02490</td>
<td>0.68521</td>
</tr>
<tr>
<td>ACT</td>
<td>0.09341</td>
<td>0.69379</td>
<td>1.00000</td>
<td>0.52336</td>
<td>0.64391</td>
<td>-0.04369</td>
<td>0.65081</td>
</tr>
<tr>
<td>ACSPT</td>
<td>0.11265</td>
<td>0.54494</td>
<td>0.52336</td>
<td>1.00000</td>
<td>0.50129</td>
<td>0.13196</td>
<td>0.82696</td>
</tr>
<tr>
<td>WGPT</td>
<td>0.03179</td>
<td>0.76331</td>
<td>0.64391</td>
<td>0.50129</td>
<td>1.00000</td>
<td>0.11696</td>
<td>0.61428</td>
</tr>
<tr>
<td>HSA</td>
<td>-0.08736</td>
<td>-0.02490</td>
<td>-0.04369</td>
<td>0.13196</td>
<td>0.11696</td>
<td>1.00000</td>
<td>0.13838</td>
</tr>
<tr>
<td>MCTOT</td>
<td>0.06696</td>
<td>0.68521</td>
<td>0.65081</td>
<td>0.82696</td>
<td>0.61428</td>
<td>0.13838</td>
<td>1.00000</td>
</tr>
</tbody>
</table>

**TABLE VI**

**CORRELATION MATRIX OF ALL VARIABLES**
Since there was a low correlation of the ACSPR examination scores with each of the three criteria, it was of no value in development of the regression equation. However, in order to determine the number of predictor variables to use in the regression equations, the following formula, from *Fundamental Statistics in Psychology and Education*, was used:

\[
F = \frac{(R_1^2 - R_2^2)(N - m_1 - 1)}{(1 - R_1^2)(m_1 - m_2)}
\]

where
- \(R_1\) = multiple R with larger number of independent variables
- \(R_2\) = multiple R with one or more variables omitted
- \(m_1\) = larger number of independent variables
- \(m_2\) = smaller number of independent variables

In the use of the F tables, the \(df_1\) degrees of freedom are given by \((m_1 - m_2)\) and the \(df_2\) degrees of freedom by \((N - m_1 - 1)\) (4, p. 403).

The 0.05 level of significance was used, and by utilization of the F test, it was determined that the two control variables, WGPR test and ACT scores, were the appropriate ones to use in development of the regression equations for predicting the MCTOT score; WGPT score, and the ACSPT score. These three regression equations were developed primarily for determination of the high and low ability students of each group.

Before progressing further into the development and utilization of the three regression equations, the correlation matrix will be discussed in greater detail.
The Correlation Matrix

Correlation values from Table VI were utilized in the equation given on Page 76 to determine whether to use one, two, or three predictor variables in each of the regression equations.

F-values ranging from approximately 4.5 to 36.4 were obtained when the use of two variable, ACT and WGPR, as predictors were compared with the use of only a single variable, ACT or WGPR. Similar F-value were obtained when the use of one variable, ACT or WGPR, was compared with the use of no variables. However, the addition of the single variable, ACSPR, to the ACT and WGPR combined variables gave insignificant values of .010, .125, and .491 for the MCTOT, WGPR, and ACSPT criteria respectively. As a result of these calculation, the ACT and WGPR scores were used as predictor variables in each of the three regression equations developed.

Correlations of the ACT scores with MCTOT scores, ACSPT scores, and WGPT scores were 0.651, 0.523, and 0.644 respectively. Correlations of the WGPR scores with the MCTOT scores, ACSPT scores, and the WGPT scores were 0.685, 0.545, and 0.763 respectively. Thus it may be seen that the WGPR score was slightly better predictor in each case than was the ACT score. Furthermore, the correlation of WGPR scores with ACT scores was 0.694. All the seven above correlation values were used in the development of the regression equations.
Other correlations between scores which were high enough to
deserve special comment were the following: MCTOT with WGPT, 0.614; ACSPT with WGPT, 0.501; and MCTOT with ACSPT, 0.827.
The high correlation of MCTOT scores with ACSPT scores may have indicated that both criteria measured similar abilities, and this helped to substantiate the content validity of the teacher-constructed multiple-choice examinations.

Development of the Regression Equations

In order to determine levels of ability for students, it was necessary to develop regression equations for predicting students' scores on the MCTOT, ACSPT, and WGPT criteria. In order to do this, $B_1$, $B_2$, and $B_3$ values were determined by solving the following three simultaneous equations according to methods given in *Psychological Statistics* (5, pp. 169-187):

\[
\begin{align*}
B_1 + B_2 r_{12} + B_3 r_{13} &= r_{y1} \\
B_1 r_{12} + B_2 + B_3 r_{23} &= r_{y2} \\
B_1 r_{13} + B_2 r_{23} + B_3 &= r_{y3}
\end{align*}
\]

The subscripts 1, 2, and 3 in the foregoing equations referred to the independent variables, while the $y$ referred to the dependent variable, the criterion. The $r$ referred to the coefficient of correlation obtained from the correlation matrix, Table VI. By solving the equations for the $B$ values, it was possible to substitute the values in the following formulas to determine multiple correlations of the variables with the three criteria:

* Used as the symbol for $\beta$. 
\[
R_{y.12} = \sqrt{B_1 r_{y1} + B_2 r_{y2}}
\]
\[
R_{y.123} = \sqrt{B_1 r_{y1} + B_2 r_{y2} + B_3 r_{y3}}
\]

The above equations were altered, in symbol only, from Equation 11.12 in Psychological Statistics (5, p. 178).

These \(R_{y.12}\) and \(R_{y.123}\) values were then incorporated into the formulas, given on p. 76, to determine whether one, two, or three independent variables should be used in the regression equations. It was determined by this method that two independent variables, the ACT scores and the WGPR scores, would be appropriate to use in each of the three regression equations.

The multiple correlation coefficient, multiple correlation coefficient squared, and the standard error of estimate for each regression equation are presented in Table VII.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Multiple Correlation Coefficient</th>
<th>Multiple Correlation Coefficient Squared</th>
<th>Standard Error of Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCTOT</td>
<td>0.727</td>
<td>0.528</td>
<td>20.91</td>
</tr>
<tr>
<td>ACSPT</td>
<td>0.581</td>
<td>0.338</td>
<td>10.51</td>
</tr>
<tr>
<td>WGPT</td>
<td>0.780</td>
<td>0.608</td>
<td>7.22</td>
</tr>
</tbody>
</table>

The following general formula, altered in symbol only from Formula 11.3 in Psychological Statistics (5, p. 173), was used for development of the specific regression equations:
\[ y = \frac{B_1 S_Y X_1}{S_1} + \frac{B_2 S_Y X_2}{S_2} + \left( \frac{M_Y - B_1 S_Y M_1}{S_1} - \frac{B_2 S_Y M_2}{S_2} \right) \]

The meaning of each symbol in the above equation follows:

- \( Y \) = dependent variable, the criterion.
- \( S_Y \) = standard deviation of all \( Y \) scores.
- \( S_1 \) = standard deviation of all scores of the first independent variable, a predictor variable.
- \( S_2 \) = standard deviation of all scores of the second independent variable, a predictor variable.
- \( X_1 \) = a specific score of a student on the first independent variable.
- \( M_Y \) = actual arithmetic mean of all \( Y \) scores.
- \( M_1 \) = actual arithmetic mean of all scores of the first independent variable.
- \( M_2 \) = actual arithmetic mean of all scores of the second independent variable.

**Findings Related to the MCTOT Criterion**

The following illustrates the use of the general regression equation for development of the regression equation for predicting MCTOT scores (dependent variable) from ACT scores (first independent variable) and WGPR scores (second independent variable).

The following values, most of which were obtained through the computer programs, were used for substitution into the general regression equation:

- \( B_1 = 0.338 \).
- \( S_Y = 30.46 \) = standard deviation of all MCTOT scores.
- \( S_1 = 4.86 \) = standard deviation of all ACT scores.
- \( B_2 = 0.451 \).
- \( S_2 = 10.43 \) = standard deviation of all WGPR scores.
$M_Y = 58.79 = \text{arithmetic mean of all MCTOT scores.}$

$M_1 = 20.08 = \text{arithmetic mean of all ACT scores.}$

$M_2 = 70.19 = \text{arithmetic mean of all WGPR scores.}$

Upon substitution of these values in the general regression equation, the following specific regression equation for predicting MCTOT scores was obtained:

$$Y_1 = 2.12 \, X_1 + 1.32 \, X_2 - 76.17$$

where $X_1$ and $X_2$ represented a student's ACT and WGPR scores respectively.

The following example, which shows the computation of the predicted MCTOT score of Student 5 in Group 1 (control group), illustrates the use of the regression equation:

$$Y_1 = 2.12 \, (21) + 1.32 \, (60) - 76.17$$

$$= 44.52 + 79.20 - 76.17 = 47.55$$

or 48 rounded off to the nearest whole number.

The predicted scores of students were used to establish the three ability levels of the combined groups. The arrangement of student scores by group and ability level, with the MCTOT as the criterion, is shown in Table VIII.

Information from Statistical Methods in Educational and Psychological Research (6, pp. 343-363) was utilized to develop a program for the computer which would assist in testing Hypotheses 1, 2, and 3 by the analysis of covariance technique. Information related to Hypotheses 1A, 1B, and 1C will be discussed in this section.
### TABLE VIII

Arrangement of Student Scores According to Group and Ability Level, MCTOT as Criterion

<table>
<thead>
<tr>
<th>Control Group</th>
<th>Experimental Group</th>
</tr>
</thead>
<tbody>
<tr>
<td><em><em>Stud. ACT WGRP MCTOT</em> MCTOT</em>*</td>
<td><em><em>Stud. ACT WGRP MCTOT</em> MCTOT</em>*</td>
</tr>
<tr>
<td><strong>No. (x1) (x2) (Pred.) (Actual)</strong></td>
<td><strong>No. (x1) (x2) (Pred.) (Actual)</strong></td>
</tr>
<tr>
<td><strong>HIGH ABILITY LEVEL</strong></td>
<td><strong>HIGH ABILITY LEVEL</strong></td>
</tr>
<tr>
<td>17 29 84 96 123</td>
<td>25 29 84 96 122</td>
</tr>
<tr>
<td>20 28 84 94 51</td>
<td>1 23 87 87 128</td>
</tr>
<tr>
<td>18 27 85 93 81</td>
<td>23 23 87 87 73</td>
</tr>
<tr>
<td>1 24 85 87 114</td>
<td>20 23 82 81 70</td>
</tr>
<tr>
<td>25 24 85 87 73</td>
<td>3 24 81 81 108</td>
</tr>
<tr>
<td>22 23 86 86 90</td>
<td>5 23 76 73 90</td>
</tr>
<tr>
<td>21 30 73 84 100</td>
<td>17 22 76 71 63</td>
</tr>
<tr>
<td>27 24 78 77 68</td>
<td>9 20 80 72 90</td>
</tr>
<tr>
<td>9 20 80 72 90</td>
<td>12 24 74 72 54</td>
</tr>
<tr>
<td>23 22 76 71 43</td>
<td></td>
</tr>
</tbody>
</table>
# TABLE VIII —Continued

<table>
<thead>
<tr>
<th>Control Group</th>
<th>Experimental Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stud. No.</td>
<td>ACT ((x_1))</td>
</tr>
<tr>
<td>---------------</td>
<td>----------------</td>
</tr>
<tr>
<td>MEDIUM ABILITY LEVEL</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>22</td>
</tr>
<tr>
<td>16</td>
<td>22</td>
</tr>
<tr>
<td>26</td>
<td>21</td>
</tr>
<tr>
<td>6</td>
<td>25</td>
</tr>
<tr>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>24</td>
<td>18</td>
</tr>
<tr>
<td>8</td>
<td>18</td>
</tr>
<tr>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>LOW ABILITY LEVEL</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>21</td>
</tr>
<tr>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>19</td>
<td>12</td>
</tr>
<tr>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
</tr>
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<td></td>
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<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In addition to testing Hypothesis 1A, concerned primarily with overall achievement due to method, and Hypotheses 1B and 1C, concerned primarily with achievement of students in specific ability levels due to method, the technique was also capable of detecting interaction between method and ability level. Thus, if one method was significantly and selectively better for one or more of the levels, this would show up in the interaction analysis.

The computer program was designed to print out deviation values for all sources of variations, which includes all squares and crossproducts involved. Table XXI, Page 135A, gives the deviation form sums of squares and crossproducts for all sources of variation, and Table X, Page 135A, gives the deviation form sums of squares and crossproducts for sources of variation plus within values. In preparing the table, all values were recorded as decimal quantities between zero and one multiplied by some power of 10. Thus the value at the top left of Table XXI was written as .49172723 5. It was therefore equivalent to 49,172.72

The deviation form sums of squares and crossproducts were next utilized for determining the information recorded in Table IX which in turn served as a test of the following hypotheses:

A. Basic college chemistry students taught by the note-test system will achieve significantly higher total scores on four teacher-constructed multiple-choice examinations than will students taught by a traditional lecture method.
B. Basic college chemistry students of the top third in student ability who have been taught by the note-test system will achieve significantly higher total scores on four teacher-constructed multiple-choice examinations than will students of the top third in student ability who have been taught by a traditional lecture method.

C. Basic college chemistry students of the bottom third in student ability who have been taught by the note-test system will achieve significantly higher total scores on four teacher-constructed multiple-choice examinations than will students of the bottom third in student ability who have been taught by a traditional lecture method.

Table IX presents the results of tests of significance related to the MCTOT scores as the criterion. The experimental group as a whole attained higher scores on the criterion than did the control group, but the extent of the difference was not sufficient to yield a significant P-value. Consequently, Hypothesis 1A was rejected.

The high ability students of the experimental group attained higher scores on the criterion than did the high-ability students of the control group; furthermore, the higher scoring was in the direction predicted. However, the low-ability students of the experimental group attained lower scores on the criterion than did the low-ability students of the control group. This lower scoring was not in the direction predicted. The extent of the difference in either level was not sufficient to produce a significant F-value. Consequently, Hypotheses 1B and 1C were rejected.
**TABLE IX**

**ANALYSIS OF COVARIANCE FOR MCTOT RAW SCORES**
**AS CRITERION**

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sums of Squares</th>
<th>Mean Squares</th>
<th>F</th>
<th>Significance Needed for Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method</td>
<td>1</td>
<td>759.7733</td>
<td>759.7733</td>
<td>1.7455</td>
<td>NS*</td>
</tr>
<tr>
<td>Level</td>
<td>2</td>
<td>932.4194</td>
<td>466.2097</td>
<td>1.0711</td>
<td>NS</td>
</tr>
<tr>
<td>Interaction</td>
<td>2</td>
<td>1574.6010</td>
<td>787.3005</td>
<td>1.8087</td>
<td>NS</td>
</tr>
<tr>
<td>Within Subgroups</td>
<td>45</td>
<td>19587.4466</td>
<td>435.2766</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Not Significant*
As shown in Table IX, the F-value for the interaction, although not significant, was higher than the F-value for either method or level. This was undoubtedly the result of the better performance of the high-ability students of the experimental group than the control group, coupled with the poorer performance of the low-ability students of the experimental group than the control group.

Since the P-values revealed no significant differences, it was not necessary to compute adjusted means for further analysis. According to Wert, Neidt, and Ahmann (6, p. 348), if no significant F-value is found in the analysis of covariance, the means adjustment process is not in order.

Even though it was not necessary to compute adjusted means for purposes of analysis, the adjusted means of the two groups as a whole were computed and compared with the actual means in Table X. It was felt that the comparison would present a clearer picture to the reader.

### TABLE X

**ACTUAL AND ADJUSTED MEANS OF MCTOT SCORES**

<table>
<thead>
<tr>
<th>Control Group</th>
<th>Experimental Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Mean</td>
<td>Adjusted Mean</td>
</tr>
<tr>
<td>58.48</td>
<td>54.80</td>
</tr>
</tbody>
</table>
Although no significant difference were obtained in the analysis of covariance, a qualitative inspection of Table XI reveals a trend which might be of value to an instructor contemplating a note-test approach to instruction. The table lists actual means of subgroups, together with the predicted means of the subgroups.

TABLE XI
ACTUAL AND PREDICTED MEANS OF MCTOT SCORES BY SUBGROUPS

<table>
<thead>
<tr>
<th>Ability Level</th>
<th>Control Group</th>
<th></th>
<th>Experimental Group</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Predicted</td>
<td>Actual</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>Mean</td>
<td>Predicted</td>
<td>Mean</td>
</tr>
<tr>
<td>High Ability Level</td>
<td>83.54</td>
<td>80.64</td>
<td>82.28</td>
<td>93.43</td>
</tr>
<tr>
<td>Medium Ability Level</td>
<td>57.89</td>
<td>43.00</td>
<td>59.50</td>
<td>63.38</td>
</tr>
<tr>
<td>Low Ability Level</td>
<td>35.28</td>
<td>43.57</td>
<td>34.45</td>
<td>34.18</td>
</tr>
</tbody>
</table>

From inspection of the table, it appears that the note-test system of teaching might be more successful if used for high-ability students than if used for low-ability students. Further experimental work with larger numbers of students would be necessary to substantiate or repudiate this belief.
Findings Related to the ACSPT Criterion

The general regression equation was used to develop a regression equation for predicting scores on the ACSPT examination. For this purpose, the following values were substituted into the equation:

- \( B_1 = 0.275 \)
- \( S_y = 12.915 \) = standard deviation of all ACSPT scores.
- \( S_1 = 4.860 \) = standard deviation of all ACT scores.
- \( B_2 = 0.350 \)
- \( S_2 = 10.429 \) = standard deviation of all WGPR scores.
- \( M_y = 17.264 \) = arithmetic mean of all ACSPT scores.
- \( M_1 = 20.076 \) = arithmetic mean of all ACT scores.
- \( M_2 = 70.189 \) = arithmetic mean of all WGPR scores.

Upon substitution of these values in the general regression equation, the following specific equation for predicting ACSPT scores was obtained:

\[ Y_2 = 0.742X_1 + 0.434X_2 - 28.17 \]

where \( X_1 \) and \( X_2 \) represented a student's ACT and WGPR scores respectively.

Computation of the predicted ACSPT score of Student 5 in Group 1 (control group) follows:

\[ Y_2 = 0.742 (21) + 0.434 (60) - 28.17 = \]
\[ 15.58 + 26.04 - 28.17 = 13.55 \]

or rounded off to the nearest whole number.

The predicted scores of students were used to establish the three ability levels of the combined groups. Arrangement of student scores by group and ability level of predicted ACSPT scores is presented in Table XII.
TABLE XII

ARRANGEMENT OF STUDENT SCORES ACCORDING TO GROUP AND ABILITY LEVEL, ACSPT AS CRITERION

<table>
<thead>
<tr>
<th>Control Group</th>
<th>Experimental Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stud. ACT WGR ACSPT* ACSPT</td>
<td>Stud. ACT WGR ACSPT* ACSPT</td>
</tr>
<tr>
<td>No. (xj) (x^) (Pred.) (Actual)</td>
<td>No. (xj) (x^) (Pred.) (Actual)</td>
</tr>
<tr>
<td><strong>HIGH ABILITY LEVEL</strong></td>
<td><strong>HIGH ABILITY LEVEL</strong></td>
</tr>
<tr>
<td>17 29 84 30 39</td>
<td>25 29 84 30 38</td>
</tr>
<tr>
<td>18 27 85 29 11</td>
<td>1 23 87 27 43</td>
</tr>
<tr>
<td>20 28 84 29 6</td>
<td>23 23 87 27 19</td>
</tr>
<tr>
<td>1 24 85 26 44</td>
<td>3 24 81 25 31</td>
</tr>
<tr>
<td>22 23 86 26 48</td>
<td>20 23 82 24 12</td>
</tr>
<tr>
<td>21 30 73 26 29</td>
<td>5 23 76 22 44</td>
</tr>
<tr>
<td>25 24 85 26 13</td>
<td>17 22 76 21 22</td>
</tr>
<tr>
<td>27 24 78 24 18</td>
<td></td>
</tr>
<tr>
<td>12 24 74 22 25</td>
<td></td>
</tr>
<tr>
<td>9 20 80 21 29</td>
<td></td>
</tr>
<tr>
<td>23 22 76 21 6</td>
<td></td>
</tr>
</tbody>
</table>

**MEDIUM ABILITY LEVEL**

| 11 22 74 20 13 | 10 20 77 20 49 |
| 16 22 71 19 10 | 24 19 76 19 2 |
| 6 25 64 18 21 | 11 22 68 18 20 |
| 26 21 71 18 11 | 13 26 61 18 21 |
| 10 16 76 17 6 | 18 23 68 18 25 |
| 4 20 67 16 0 | 16 21 68 17 14 |
| 24 18 70 16 5 | 26 21 66 16 13 |
| 8 18 67 14 14 | 12 20 64 14 21 |
TABLE XII  --Continued

<table>
<thead>
<tr>
<th>Control Group</th>
<th></th>
<th>Experimental Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stud. No. (x1) (x2) (Pred.) (Actual)</td>
<td>Stud. No. (x1) (x2) (Pred.) (Actual)</td>
<td></td>
</tr>
<tr>
<td><strong>LOW ABILITY LEVEL</strong></td>
<td><strong>LOW ABILITY LEVEL</strong></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>15</td>
<td>72</td>
</tr>
<tr>
<td>5</td>
<td>21</td>
<td>60</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>67</td>
</tr>
<tr>
<td>15</td>
<td>17</td>
<td>59</td>
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<td>7</td>
<td>11</td>
<td>56</td>
</tr>
<tr>
<td>19</td>
<td>10</td>
<td>60</td>
</tr>
<tr>
<td>7</td>
<td>13</td>
<td>52</td>
</tr>
<tr>
<td>4</td>
<td>13</td>
<td>48</td>
</tr>
</tbody>
</table>

*Predicted
Table XII presents the data which were subjected to the analysis of covariance, using the same program as was used previously with the MCTOT scores as the criterion.

Table XIII, Page 135B, presents the deviation form sums of squares and crossproducts for all sources of variation, and Table XXIV, Page 135B, presents the deviation form sums of squares and crossproducts for sources of variation plus within values. The deviation form sums of squares and crossproducts were utilized for determining the information recorded in Table XIII as a test of the significance of differences related to Hypotheses 2A, 2B, and 2C:

Hypothesis 2: Using adjusted criterion means,

A. Basic college chemistry students taught by the note-test system will score significantly higher on the American Chemical Society-National Science Teachers Association Cooperative Examination in High School Chemistry than will students taught by a traditional lecture method.

B. Basic college chemistry students of the top third in student ability who have been taught by the note-test system will score significantly higher on the American Chemical Society-National Science Teachers Association Cooperative Examination in High School Chemistry than will students of the top third in student ability who have been taught by a traditional lecture method.

C. Basic college chemistry students of the bottom third in student ability who have been taught by the note-test system will score significantly higher on the American Chemical Society-National Science Teachers Association Cooperative Examination in High School Chemistry than will students of the bottom third in
<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>Degrees of Freedom</th>
<th>Mean Squares</th>
<th>Sum of Squares</th>
<th>Significance Variance Needed for Significance Needed For</th>
<th>Significance Variance Needed For Within Subgroups</th>
<th>Significance Variance Needed For Action</th>
<th>Significance Variance Needed For Level Method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

```
TABLE XIII
ANALYSIS OF COVARIANCE FOR ASCF AS CRITERION
```
student ability who have been taught by a traditional lecture method.

No significant differences are indicated in Table XIII for Hypotheses 2A, 2B, and 2C. The P-value of 1.6476 obtained in comparing the ACSPT scores of the two groups as a whole, although not significant, was in the direction predicted by Hypotheses 2A. Nevertheless, Hypothesis 2A was rejected. The small and insignificant P-value of 0.4485 obtained from the level variation made it mandatory to reject Hypotheses 2B and 2C. The P-value of 1.2354 for the interaction disclosed that, for one level than for any other.

Using the ACSPT examination as the criterion, since no significant differences were obtained, it was not necessary to compute adjusted means for further analysis. However, for purposes of clarity, adjusted means were computed and shown in Table XIV

TABLE XIV

ACTUAL AND ADJUSTED MEANS OF ACSPT SCORES

<table>
<thead>
<tr>
<th>Control Group</th>
<th>Experimental Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Mean</td>
<td>Adjusted Mean</td>
</tr>
<tr>
<td>16.37</td>
<td>15.27</td>
</tr>
<tr>
<td>Actual Mean</td>
<td>Adjusted Mean</td>
</tr>
<tr>
<td>18.19</td>
<td>19.33</td>
</tr>
</tbody>
</table>
Actual and predicted scores according to group and ability level are presented in Table XV. By inspection of the data, one may conjecture that the note-test system might have a greater chance of success than the traditional lecture system when used with high ability-students and a smaller chance of success when used with low-ability students if the ACSPT examination serves as the criterion.

TABLE XV

ACTUAL AND PREDICTED MEANS OF ACSPT SCORES BY SUBGROUPS

<table>
<thead>
<tr>
<th></th>
<th>Control Group</th>
<th>Experimental Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Predicted Mean</td>
<td>Actual Mean</td>
</tr>
<tr>
<td>High Ability Level</td>
<td>24.45</td>
<td>24.36</td>
</tr>
<tr>
<td>Medium Ability Level</td>
<td>16.89</td>
<td>10.56</td>
</tr>
<tr>
<td>Low Ability Level</td>
<td>9.14</td>
<td>11.28</td>
</tr>
</tbody>
</table>

Findings Related to the WGPT Criterion

As shown in Table VII, p. 79, the square of the multiple correlation of WGPT scores with the ACT and WGPR scores was 0.608.
Thus approximately 61 per cent of the variance in scores on the WGPT criterion could be accounted for by scores on the WGPR examination and ACT scores.

After computing beta values from the appropriate set of linear equations (p. 78), the following values were substituted into the general regression equation to develop the specific regression equation for predicting WGPT scores:

\[ b_1 = 0.214, \]

\[ s_y = 11.528 = \text{standard deviation of all WGPT scores}, \]

\[ s_1 = 4.860 = \text{standard deviation of all ACT scores}, \]

\[ b_2 = 0.610, \]

\[ s_2 = 10.429 = \text{standard deviation of all WGPR scores}, \]

\[ m_y = 70.528 = \text{arithmetic mean of all WGPT scores}, \]

\[ m_1 = 20.076 = \text{arithmetic mean of all WGPR scores}. \]

Upon substituting these values into the appropriate general equation, the final specific regression equation for predicting WGPT scores was obtained:

\[ y_3 = 0.507x_1 + 0.675x_2 + 12.99 \]

in which \( x_1 \) and \( x_2 \) were the student's ACT and WGPR scores respectively.

The regression equation was utilized for predicting the WGPT scores of all students in the two groups. For example, in predicting the WGPT score for Student 5 in Group 1, the following computation was necessary:
\[ Y_3 = 0.507 \times 21 + 0.675 \times 60 + 12.99 = 10.647 + 40.50 + 12.99 = 64.14 = \]

64 rounded off to the nearest whole number.

Table XVI presents an arrangement of student scores by group and ability level of predicted WGPT scores.

**TABLE XVI**

**ARRANGEMENT OF STUDENT SCORES ACCORDING TO GROUP AND ABILITY LEVEL, WGPT AS CRITERION**

<table>
<thead>
<tr>
<th>Control Group</th>
<th>Experimental Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stud. No.</td>
<td>ACT (X_1)</td>
</tr>
<tr>
<td>HIGH ABILITY LEVEL</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>29</td>
</tr>
<tr>
<td>18</td>
<td>27</td>
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<tr>
<td>20</td>
<td>28</td>
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<td>12</td>
<td>24</td>
</tr>
<tr>
<td>23</td>
<td>22</td>
</tr>
</tbody>
</table>

*Predicted
TABLE XVI --Continued

<table>
<thead>
<tr>
<th>Stud. No.</th>
<th>ACT (X₁)</th>
<th>WGPR (X₂)</th>
<th>WGPT* (Pred.)</th>
<th>WGPT (Actual)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**MEDIUM ABILITY LEVEL**

<table>
<thead>
<tr>
<th>Stud. No.</th>
<th>ACT (X₁)</th>
<th>WGPR (X₂)</th>
<th>WGPT* (Pred.)</th>
<th>WGPT (Actual)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>22</td>
<td>74</td>
<td>74</td>
<td>74</td>
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<tr>
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<td>25</td>
<td>64</td>
<td>70</td>
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</tr>
<tr>
<td>26</td>
<td>21</td>
<td>71</td>
<td>71</td>
<td>71</td>
</tr>
<tr>
<td>10</td>
<td>16</td>
<td>76</td>
<td>72</td>
<td>70</td>
</tr>
<tr>
<td>4</td>
<td>20</td>
<td>67</td>
<td>69</td>
<td>65</td>
</tr>
<tr>
<td>24</td>
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<tr>
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<tr>
<td>8</td>
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<td>68</td>
<td>73</td>
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<tr>
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<td>2</td>
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<tr>
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<tr>
<td>7</td>
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<td>56</td>
<td>58</td>
<td>68</td>
</tr>
</tbody>
</table>

**LOW ABILITY LEVEL**

<table>
<thead>
<tr>
<th>Stud. No.</th>
<th>ACT (X₁)</th>
<th>WGPR (X₂)</th>
<th>WGPT* (Pred.)</th>
<th>WGPT (Actual)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>20</td>
<td>64</td>
<td>67</td>
<td>58</td>
</tr>
<tr>
<td>8</td>
<td>16</td>
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<td>66</td>
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<td>22</td>
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<tr>
<td>6</td>
<td>10</td>
<td>45</td>
<td>51</td>
<td>64</td>
</tr>
</tbody>
</table>

*Predicted
The same computer program used previously with the MCTOT and ACSPT as criteria was utilized again with the WGPT as criterion for the purpose of printing out the deviation form sums of squares and crossproducts for sources of variation; also, the deviation form sums of squares and crossproducts for sources of variation plus within values. These printed out values are shown in Tables XXV, Page 135C, and XXVI, Page 135C, respectively.

The information in Table XVII was computed from the data in Tables XXV and XXVI. This information provided the necessary tests of significance for Hypotheses 3A, 3B, and 3C, which follow:

Hypothesis 3: Using adjusted criterion means,

A. Basic college chemistry students taught by the note-test system will score significantly higher on the Watson-Glaser Critical Thinking Appraisal than will students taught by a traditional lecture method.

B. Basic college chemistry students of the top third in student ability who have been taught by the note-test system will score significantly higher on the Watson-Glaser Critical Thinking Appraisal than will students of the top third in student ability who have been taught by a traditional lecture method.

C. Basic college chemistry students of the bottom third in student ability who have been taught by the note-test system will score significantly higher on the Watson-Glaser Critical Thinking Appraisal than will students of the bottom third in student ability who have been taught by a traditional lecture method.
### TABLE XVII

**ANALYSIS OF COVARIANCE FOR WGPT AS CRITERION**

<table>
<thead>
<tr>
<th>Sources of Variation</th>
<th>Degrees of Freedom</th>
<th>Sums of Squares</th>
<th>Mean Square</th>
<th>F</th>
<th>Significance</th>
<th>F Needed for Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method</td>
<td>1</td>
<td>104.0484</td>
<td>104.0484</td>
<td>1.9836</td>
<td>NS*</td>
<td>4.05</td>
</tr>
<tr>
<td>Level</td>
<td>2</td>
<td>198.5089</td>
<td>99.2545</td>
<td>1.8922</td>
<td>NS</td>
<td>3.20</td>
</tr>
<tr>
<td>Interaction</td>
<td>2</td>
<td>70.6179</td>
<td>35.3089</td>
<td>0.673</td>
<td>NS</td>
<td>3.20</td>
</tr>
<tr>
<td>Within Subgroups</td>
<td>45</td>
<td>2360.4302</td>
<td>52.4540</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Not Significance
Results of significance tests for Hypotheses 3A, 3B, and 3C are presented in Table XVII. The F-value for method reveals no significant difference in WGPT scores of the two groups as a whole. Scores on the criterion were higher for the control group than for the experimental group; also, the difference in mean scores on the criterion between the two groups was in the direction opposite to that predicted by Hypothesis 3A. However, because of the insignificant F-value, Hypothesis 3A was rejected.

The F-value of 1.8922 for level was not sufficient for retention of either Hypothesis 3B or 3C, that is, neither method was found to be superior to the other when used with either the high or low ability level students.

Since the control group attained on the criterion an arithmetical mean of several points more in both the middle and lower level students and only slightly less in the top ability level students, the F-value for the interaction effect was very low and insignificant.

As with the other two criteria previously discussed, it was not necessary to compute the adjusted mean for the WGPT criterion. In the interest of clarity, however, these adjusted means were computed and presented in Table XVIII.

**TABLE XVIII**

ACTUAL AND ADJUSTED MEANS OF WGPT SCORES

<table>
<thead>
<tr>
<th>Control Group</th>
<th>Experimental Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Mean</td>
<td>Adjusted Mean</td>
</tr>
<tr>
<td>73.26</td>
<td>72.00</td>
</tr>
</tbody>
</table>
Table IXI presents actual and predicted scores on the WGPT criterion for each of the subgroups involved in the study.

**TABLE XIX**

**ACTUAL AND PREDICTED MEANS OF WGPT SCORES BY SUBGROUPS**

<table>
<thead>
<tr>
<th></th>
<th>Pred. * Mean</th>
<th>Actual Mean</th>
<th>Pred. * Mean</th>
<th>Actual Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control Group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>High Ability Group</strong></td>
<td>79.27</td>
<td>81.27</td>
<td>79.29</td>
<td>83.00</td>
</tr>
<tr>
<td><strong>Medium Ability Group</strong></td>
<td>70.44</td>
<td>70.22</td>
<td>71.12</td>
<td>65.00</td>
</tr>
<tr>
<td><strong>Low Ability Group</strong></td>
<td>62.00</td>
<td>64.57</td>
<td>61.73</td>
<td>59.91</td>
</tr>
</tbody>
</table>

* Predicted

**Findings Related to the Attitude Criterion**

Since no pre-test of attitude was administered, it was not feasible to make the same types of hypotheses concerning this criterion as were made with respect to the other two criteria. As may be determined by reference to the correlation matrix, p. 75, extremely low correlations of the HSA scores with any of the three pre-measures would have prevented the development of a meaningful regression equation for prediction of scores on the attitude criterion. Therefore, only the following single hypothesis was made concerning student attitudes:
Hypothesis 4: Basic college chemistry students who have been taught by the note-test system will score significantly higher on the Band Scale of Attitudes Toward College Courses: A Scale to Study Attitudes Toward College Courses than will students who have been taught by a traditional lecture method.

Although it was possible that a significant difference in attitudes of students in the two groups existed at the onset of the experiment, it does not appear probable that this difference was present. Strengthening this supposition was the fact that in three pre-measures, which were subjected to comparisons by means of the t-test, no significant difference was found.

Table XX compares the attitude scores of the two groups at the end of the semester. A t-test comparison revealed the difference in the mean attitude scores of the two student groups was significant at the 0.01 level. The t-value obtained was 2.78. Thus, hypothesis 4 was accepted.

<table>
<thead>
<tr>
<th>Control Group</th>
<th>Experimental Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arithmetic</td>
<td>Standard</td>
</tr>
<tr>
<td>Mean</td>
<td>Deviation</td>
</tr>
<tr>
<td>28.33</td>
<td>18.61</td>
</tr>
</tbody>
</table>

TABLE XX
COMPARISON OF SCORES ON THE ATTITUDE CRITERION
CHAPTER BIBLIOGRAPHY


CHAPTER IV

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS
FOR FURTHER STUDY

This chapter presents a brief summary of the study, findings of the study, conclusions drawn as a result of the analyses, and recommendations for further study.

Summary

Two classes of students who were enrolled in basic college chemistry were utilized in an attempt to determine the relative effects of a note-test system and a traditional lecture method of teaching on student achievement, critical thinking ability, and attitude toward a college basic chemistry course.

The classes were consecutive, taught by the same instructor, and consisted of approximately equal numbers of students. The number of students which comprised the control group was 27, while 26 students made up the experimental group.

Comparisons of the two groups at the onset of the experiment were made by means of the $t$-test with respect to the following variables: (1) ACT composite scores, (2) scores on the Watson-Glaser Critical Thinking Appraisal, and (3) scores on the American Chemical Society-National Science Teachers Association Cooperative Examination, Form 1963, Advanced Version.
These comparisons revealed no significant differences in the two groups, thus indicating that students in the two groups were of the same general population.

Common criteria which were utilized in the two groups for purposes of comparison follow: (1) four teacher-constructed multiple-choice examinations, (2) the ACS-NSTA Cooperative Examination in High School Chemistry. Form 1963. Advanced Version, administered as a post-test, (3) the Watson-Glaser Critical Thinking Appraisal. Form YM, administered as a post-test, and (4) the Hand Scale of Attitudes Toward College Courses: A Scale to Study Attitudes Toward College Courses.

A correlation matrix showing correlations between all dependent and independent variables was developed to assist in the derivation of regression equations. By multiple linear regression and correlation analysis, it was possible to develop three regression equations for predicting student scores on the first three criteria listed in the preceding paragraph. These predicted scores were utilized for placing students in high, medium, and low student ability levels for each of the three criteria.

It was determined by the multiple linear regression technique and related analyses that the ACT composite scores of students plus the scores on the Watson-Glaser Critical Thinking Appraisal, administered as a pre-test, would be useful predictors for each of the three criteria.

The three predictor equations developed were those shown below. Symbols used were listed in the section, Definition of Terms.
1. \[ MCTOT = 2.12 \text{ACT} + 1.32 \text{WGPR} - 76.17 \]
2. \[ ACSPT = 0.742 \text{ACT} + 0.434 \text{WGPR} - 28.17 \]
3. \[ WGPT = 0.507 \text{ACT} + 0.675 \text{WGPH} + 12.99 \]

Multiple correlation coefficients and standard error of estimates related to each of the three equations were presented in Table VII, p. 79.

Subsequent to placing students in high, medium, and low ability levels and obtaining all the necessary data, analyses of results were made primarily by the analysis of covariance.

At the end of the semester, a determination of student attitudes toward the chemistry course was made by administering the Hand Scale of Attitudes Toward College Courses: A Scale to Study Attitudes Toward College Courses.

The experiment and subsequent analyses of data have served to fulfill the six initial purposes of the study. The purposes of the study, together with comments related to each purpose were those listed and considered below:

1. To determine the relative effectiveness of the note-test system and the traditional lecture system of teaching basic college chemistry on student achievement.

Achievement of each student in the course was measured by two criteria: the total score on four teacher-constructed multiple-choice examinations and the score on the ACS-NSTA Cooperative Examination in High School Chemistry, Form 1963, Advanced Version. On both criteria, the overall mean score
for the entire experimental group was higher than that for the control group. The MCTOT mean score was 58.48 for the control group and 59.11 for the experimental group. On the ACS-NSTA examination, the control group increased from a mean of 5.67 on the pre-test to 16.37 on the post-test. The increase in the experimental group was from 6.08 to 18.19. By means of analysis of covariance, it was determined that there was no significant difference in the groups on either of the two achievement criteria.

2. To determine the relative effectiveness of the note-test system and the traditional lecture system of teaching basic college chemistry on student ability to think critically and reflectively.

The Watson-Glaser Critical Thinking Appraisal was administered both as a pre-test and as a post-test. The mean score of the control group increased from 72.00 on the pre-test to 73.26 on the post-test. The mean score of the experimental group decreased from 68.31 on the pre-test to 67.69 on the post-test. Through analysis of covariance, it was determined that the groups did not differ significantly in the ability to think critically and reflectively when the Watson-Glaser Critical Thinking Appraisal was used as the measuring instrument.

3. To determine the relative effectiveness of the note-test system and a traditional lecture system of teaching basic college chemistry on student attitudes toward the chemistry course.
The mean score at the end of the semester on a Scale to Study Attitudes Toward College Courses was 28.33 for the control group and 43.77 for the experimental group. This difference was significant at the 0.01 level. Although no pre-measurement of student attitudes was obtained, since no other pre-test variable showed a significant difference, it seemed improbable that a significant difference in attitudes of the two groups existed at the onset of the experiment. If the assumption of no significant difference in pre-attitudes of students can be accepted, the note-test system of presentation was superior to the traditional lecture method in formulating positive attitudes toward the chemistry course.

4. To determine if the relative effects of the note-test system of teaching and the traditional lecture system of teaching, on achievement, are dependent upon student ability.

Table XI indicated that, although the means of predicted MCTOT scores in the high ability level were relatively close together for both groups (1.26 points more for the control group), the actual difference in the MCTOT mean score was 12.79 points, with the experimental group exceeding the control group. Consideration of the same criterion in the low ability level revealed almost opposite results. The predicted mean MCTOT score for the low ability level was 0.83 point higher for the control group than for the experimental group. However, the actual mean MCTOT score for the control group was 9.39 points higher than for the experimental group. Although the
middle ability level students were not included in the hypotheses as a level for comparison, it was noted that the actual MCTOT mean score for the control group was 14.89 points lower than predicted and the actual MCTOT mean score for the experimental group was 3.88 points higher than predicted.

Table XV, which presented data related to the ACSPT examination as the criterion, indicated practically the same trends, relationships, and comparative achievement as was the case with the MCTOT as the criterion.

When achievement was considered, it appeared that the high ability students of the experimental group fared better than did the high ability students of the control group. The low ability students of the control group, however, outperformed the low ability students of the experimental group on the two criteria of achievement. Nevertheless, analyses of the interaction effects by the analysis of covariance resulted in F-values too low to be statistically significant.

5. To determine if the relative effects of the note-test system of teaching and the traditional lecture system of teaching, on critical thinking, are dependent upon student ability.

Table XIX indicated that the mean score of high ability level students on the WGPT examination was 1.73 points lower for the control group than the mean score of the high ability level students in the experimental group. Predicted means were almost identical for the two groups.
In the low student ability level, the mean score on the WGPT examination of the control group was 4.66 points higher than the mean score of the experimental group. There was only 0.16 point difference in the predicted means of the two groups. In the middle student ability level, the control group also attained higher scores, 5.22 points separating the two means. The F-value for interaction between method and ability level was insignificant.

Findings

Based upon the data and statistical analyses, the following findings were revealed:

1. When the criterion of achievement was measured by the total scores on four teacher-constructed multiple-choice examinations,

   A. Scores of students taught by the note-test system did not differ significantly from scores of students taught by a traditional lecture method.

   B. Scores of students of the top third in student ability taught by the note-test system did not differ significantly from scores of students of the top third in student ability taught by a traditional lecture method.

   C. Scores of students of the bottom third in student ability taught by the note-test system did not differ significantly from scores of students of the bottom third in student ability taught by a traditional lecture method.
2. When the criterion of achievement was measured by scores on the American Chemical Society-National Science Teachers Association Cooperative Examination in High School Chemistry, Form 1963, Advanced Version.
   A. Scores of students taught by the note-test system did not differ significantly from scores of students taught by a traditional lecture method.
   B. Scores of students of the top third in student ability taught by the note-test system did not differ significantly from scores of students of the top third in student ability taught by a traditional lecture method.
   C. Scores of students of the bottom third in student ability taught by the note-test system did not differ significantly from scores of students of the bottom third in student ability taught by a traditional lecture method.

3. When the criterion of critical thinking ability was measured by scores on the Watson-Glaser Critical Thinking Appraisal, Form YM.
   A. Scores of students taught by the note-test system did not differ significantly from scores of students taught by a traditional lecture method.
   B. Scores of students of the top third in student ability taught by the note-test system did not differ significantly from scores of students of the top third in student ability taught by a traditional lecture method.
C. Scores of students of the bottom third in student ability taught by the note-test system did not differ significantly from scores of students of the bottom third in student ability taught by a traditional lecture method.

4. When the criterion of student attitude toward the chemistry course was measured by *A Scale to Study Attitudes Toward College Courses*, scores of students taught by the note-test system were significantly higher than scores of students taught by a traditional lecture method.

Although no significant differences in achievement were obtained, the results revealed the following conspicuous trends: With achievement as the criterion, students of high ability appeared to perform better under the note-test system of teaching than under the traditional lecture method approach, while low ability students appeared to perform better under the traditional lecture method approach than under the note-test system approach. Middle ability students of the note-test group outachieved the middle ability students of the lecture group on both achievement criteria. Those trends were not sufficient, however, to yield significant P-values for the interaction of method with ability.

It was concluded, by inspection of the data, that attitude scores showed little or no correlation with either WCPT or achievement scores. In fact, the mean attitude score of the experimental group students who were placed in the lowest third of student ability insofar as achievement was concerned was second highest of the six subgroups. This was true, even though
that group of students had the lowest mean scores on both achievement criteria and on the WGPT examination.

Conclusions

The findings and analyses of data of the study appeared to justify the following conclusions:

1. Neither the note-test system nor the traditional lecture system of teaching basic college chemistry is clearly superior to the other in bringing about student achievement in basic college chemistry. This appears to be valid when using either of the two achievement criteria of the study.

2. It appears that the note-test system approach might have a better chance of success in bringing about achievement when used with high ability students than when used with low ability students. On the other hand, it appears that low ability students may thrive better under a traditional lecture system approach than under a note-test system approach.

3. Neither the note-test system nor the traditional lecture system, when used for instructing basic college chemistry, is superior to the other in increasing the ability to think critically and reflectively. Rather, it appears that specific and intensive efforts by the instructor to increase the critical thinking ability of students must be exerted.

4. The note-test system of teaching appears to be superior to the traditional lecture system of teaching in producing high positive attitudes of students toward the basic
college chemistry course. The following factors, prevalent in a class taught by the note-test system, may be responsible for this: (1) students are provided with outlines of material which assists in their study, (2) students are allowed a great deal of time to ask questions concerning difficult material, (3) feedback is provided for students by discussing the short tests immediately after completion of the tests, and (5) students are required to do much out-of-class preparation before discussing related material in class. This may result in more familiarity with class discussion topics and more active student involvement.

Recommendations

Although the lowest ability level students of the experimental section failed to achieve as satisfactorily as did the lowest ability level students of the control section, they demonstrated excellent attitudes toward the chemistry course at the end of the semester. This indicated a possibility of too rapid coverage of material or too little assistance for those students, or a combination of the two factors. In order to alleviate these conditions for the lowest ability level students and to strengthen the probability of success of the note-test system for all students, the following suggestions are offered:

1. Do not require the lowest ability students to cover as much material as was covered in the present experiment.

2. Use an easily understandable text which contains much expository material related to the most difficult topics.
Although the test used in the present experiment was found to be satisfactory, other readily available reference material would also be desirable.

3. Provide extra assistance in the form of solved problems, showing clearly each step of the solving process. These problems should be similar to those assigned the students.

4. Provide readily available programmed material related to difficult topics.

5. Return worked problems assignments to students shortly after they are handed in. The return of these papers should be delayed no longer than the first class period following receipt of assignments.

6. The worked problem assignments should be evaluated more carefully than was possible in the present experiment. If time permits, pertinent helpful suggestions written on the papers would be desirable.

Recommendations for Further Study

The following recommendations for further study are offered, together with the reason or reasons for each recommendation.

1. Further studies of the same general type should be made which include larger numbers of students, other types of colleges and universities, and other instructors. Those studies would serve to increase or decrease the meaningfulness of results in the present study which in turn would increase or decrease the validity of the note-test system of teaching chemistry in various settings.
2. Further studies of attitudes of students toward the basic college chemistry course should be conducted in order to determine specific factors which are conducive to positive attitudes. Those attitude studies would assist instructors in bringing about positive attitude formation, thereby contributing to the encouragement of students to continue work in chemistry.

3. Although the development of critical thinking ability is frequently given as one of the objectives of chemistry teaching, more studies should be conducted to determine if and how critical thinking abilities of students may be consistently and significantly increased as a result of one or more courses in chemistry. In order to continue to encourage students to take chemistry on the basis of its potential for increasing critical thinking ability, more concrete evidence in the form of achieving success in attaining specific behavioral objectives should be sought.

4. Since it appeared that students in the top third ability level of the note-test group developed satisfactorily along lines of achievement and critical thinking ability, in addition to maintaining or developing positive attitudes toward the chemistry course, it is suggested that the note-test system of teaching be further utilized with high ability students in basic college chemistry. Further studies involving only high ability students might prove fruitful. In addition, it is suggested that statistical studies of the note-test system of teaching more advanced college chemistry courses be made.
5. It is suggested that further studies of the note-test system of teaching low ability students be undertaken, but that the amount of material covered in the course be reduced, for it seemed possible that too much content was partially responsible for their low achievement level, even though the students of that level demonstrated high positive attitudes toward the course.

6. The note-test system of teaching should, in controlled experiments, be compared with methods of teaching other than the traditional lecture method. For example, it should be compared with programmed material, audio-tutorial methods, programmed lecture methods, etc.

7. A study of student attitude change as a result of the note-test system of teaching basic college chemistry should be made. It is suggested that all students be taught alike for two or three weeks. This would be sufficient time to allow an attitude inventory concerning the chemistry course to be given to the students for the purpose of initial comparison. After the initial inventory, the note-test system and any other designated system could be instituted. In an experiment of this type, attitude scores and changes would be more meaningful.
<table>
<thead>
<tr>
<th>Number of Periods</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Pre-Test: American Chemical Society-National Science Teachers Association Cooperative Examination in High School Chemistry.</td>
</tr>
<tr>
<td>1</td>
<td>Pre-Test: Watson-Glaser Critical Thinking Appraisal.</td>
</tr>
<tr>
<td>35</td>
<td>Consideration of content of course: 10 Parts, requiring 4 days each for 5 Parts and 3 days each for 5 Parts.</td>
</tr>
<tr>
<td>5</td>
<td>Three 40-item multiple-choice examinations and one 50-item multiple-choice examination.</td>
</tr>
<tr>
<td>1</td>
<td>Post-Test: Watson-Glaser Critical Thinking Appraisal.</td>
</tr>
<tr>
<td>1</td>
<td>Hand Scale of Attitudes Toward College Courses: A Scale to Study Attitudes Toward College Courses.</td>
</tr>
<tr>
<td>2</td>
<td>Post-Test: American Chemical Society-National Science Teachers Association Cooperative Examination in High School Chemistry.</td>
</tr>
</tbody>
</table>
Content of Parts Which Comprised the First Semester Chemistry Course

<table>
<thead>
<tr>
<th>Parts</th>
<th>Chapters in Text</th>
<th>Titles of Chapters in Text**</th>
<th>Page Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Methods of Chemistry</td>
<td>3-34</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Nature of Matter</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>Atoms</td>
<td>35-78</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>Chemical Bond</td>
<td>79-102</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>Stoichiometry</td>
<td>103-132</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>Cases</td>
<td>133-166</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>Liquids</td>
<td>167-190</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Solids</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>9</td>
<td>Changes of State</td>
<td>191-205</td>
</tr>
<tr>
<td>8</td>
<td>10</td>
<td>Solutions</td>
<td>207-244</td>
</tr>
<tr>
<td>9*</td>
<td>11</td>
<td>Colloids</td>
<td>245-268</td>
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<tr>
<td></td>
<td>12</td>
<td>Chemical Kinetics</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>13</td>
<td>Chemical Equilibrium</td>
<td>269-292</td>
</tr>
<tr>
<td>11</td>
<td>14</td>
<td>Electrochemistry</td>
<td>293-320</td>
</tr>
</tbody>
</table>

*Study of Part 9 was omitted in both groups

Comparison of the Note-Test System with the Traditional Lecture Method

How They Were Alike

1. The same textbook was used for both groups.

2. The same content was considered in both groups.

3. The same type of laboratory experiences were given in both groups.

4. The same instructor taught both groups.

5. The same instructor lectured in both groups. Lecture time differed greatly.

6. Demonstrations, movies, overhead projectuals, and other types of media used in one group were used in the other group.

7. Both groups received the same four multiple-choice examinations.

8. Both groups took the ACS-NSTA Cooperative Examination in High School Chemistry, Form 1961, Advanced Version as a pre-test and as a post-test.

9. Both groups were given the Hand Scale of Attitudes Toward College Courses during the final week for the purpose of determining attitudes toward the chemistry course.

10. Both groups took the Watson-Glaser Critical Thinking Appraisal as a pre-test and as a post-test.

11. Problem assignments were the same in both groups.
How They Were Different

1. Lecture time: Approximately three times as much lecture time was used in the traditional lecture group as in the note-test group.

2. At least one-third total class time in the note-test group was reserved for consideration of student questions.

3. Pre-class study by the students was required in the note-test group, but it was not necessarily required in the traditional lecture group.

4. Problem assignments in the note-test group were due before discussing the related material in class, but they were not due in the traditional lecture group until the last day of consideration of the related material in class.

5. Independent study was necessary to a much greater extent in the note-test group than in the traditional lecture group because the lecture time for the note-test group was much less, and because pre-class preparation was demanded in the note-test method.

6. Mimeographed lecture notes were provided students of the note-test group several days prior to consideration of the material in class. The lecture notes were not given students of the traditional lecture group, but were used by the instructor as a guide.

7. Students of the note-test group took a 30-minute short answer type examination after each of the 10 parts which comprised the course. Students of the traditional lecture group did not take these examinations, but the 30-minutes were utilized as lecture time.

8. Students of the note-test group were more actively involved than those of the traditional lecture group.
## Period-by-Period Outline of Activities Which was Followed in Both Groups

<table>
<thead>
<tr>
<th>Period</th>
<th>Note-Test Class</th>
<th>Lecture Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Administer first half of pre-test <em>(ACS-NSTA Cooperative Examination in High School Chemistry, Form 1963, Advanced Version)</em>.</td>
<td>Same</td>
</tr>
<tr>
<td>2</td>
<td>Administer second half of pre-test.</td>
<td>Same</td>
</tr>
<tr>
<td>4</td>
<td>Take up problem assignments of Part 1; hand out Part 2, with problem assignments of Part 2; instructor covers highlights of Part 1.</td>
<td>Lecture by instructor: 1st third of Part 1; hand out problem assignments of Part 1, due Period 6.</td>
</tr>
<tr>
<td>6</td>
<td>Short-answer type examination over Part 1 (30 min.); discuss examination over Part 1.</td>
<td>Lecture by instructor: last third of Part 1; take up problem assignments of Part 1.</td>
</tr>
<tr>
<td>7</td>
<td>Take up problem assignments of Part 2; hand out Part 3, with problem assignments of Part 3; instructor covers most of highlights of Part 2.</td>
<td>Lecture by instructor: 1st fourth of Part 2; hand out problem assignments of Part 2, due Period 10.</td>
</tr>
<tr>
<td>Period</td>
<td>Note-Test Class</td>
<td>Lecture Class</td>
</tr>
<tr>
<td>--------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>8</td>
<td>Instructor completes highlights of Part 2; students ask questions on Part 2.</td>
<td>Lecture by instructor: 2nd fourth of Part 2.</td>
</tr>
<tr>
<td>9</td>
<td>Students ask questions on Part 2.</td>
<td>Lecture by instructor: 3rd fourth of Part 2.</td>
</tr>
<tr>
<td>10</td>
<td>Short-answer type examination over Part 2 (30 min.); discuss examination over Part 2.</td>
<td>Lecture by instructor: last fourth of Part 2; take up problem assignments of Part 2.</td>
</tr>
<tr>
<td>11</td>
<td>40-item multiple-choice examination over Parts 1 and 2.</td>
<td>40-item multiple-choice examination over Parts 1 and 2.</td>
</tr>
<tr>
<td>12</td>
<td>Take up problem assignments of Part 3; hand out Part 4, with problem assignments of Part 4; instructor covers highlights of Part 3.</td>
<td>Lecture by instructor: 1st third of Part 3; hand out problems assignments of Part 3, due Period 14.</td>
</tr>
<tr>
<td>13</td>
<td>Students ask questions on Part 3.</td>
<td>Lecture by instructor: 2nd third of Part 3.</td>
</tr>
<tr>
<td>14</td>
<td>Short-answer type examination over Part 3 (30 min.); discuss examination over Part 3.</td>
<td>Lecture by instructor: last third of Part 3; take up problem assignments of Part 3.</td>
</tr>
<tr>
<td>15</td>
<td>Take up problem assignments of Part 4; hand out Part 5, with problem assignments of Part 5; instructor covers most of highlights of Part 4.</td>
<td>Lecture by instructor: 1st fourth of Part 4; hand out problem assignments of Part 4, due Period 18.</td>
</tr>
<tr>
<td>16</td>
<td>Instructor completes highlights of Part 4; students ask questions on Part 4.</td>
<td>Lecture by instructor: 2nd fourth of Part 4.</td>
</tr>
<tr>
<td>17</td>
<td>Students ask questions on Part 4.</td>
<td>Lecture by instructor: 3rd fourth of Part 4.</td>
</tr>
<tr>
<td>Period</td>
<td>Note-Test Class</td>
<td>Lecture Class</td>
</tr>
<tr>
<td>--------</td>
<td>----------------</td>
<td>--------------</td>
</tr>
<tr>
<td>18</td>
<td>Short-answer type examination over Part 4 (30 min.); discuss examination over Part 4.</td>
<td>Lecture by instructor: last fourth of Part 4; take up problem assignments of Part 4.</td>
</tr>
<tr>
<td>19</td>
<td>Take up problem assignments of Part 5; hand out Part 6, with problem assignments of Part 6; instructor covers most of highlights of Part 5.</td>
<td>Lecture by instructor: 1st fourth of Part 5; hand out problem assignments of Part 5, due Period 22.</td>
</tr>
<tr>
<td>20</td>
<td>Instructor completes highlights of Part 5; students ask questions on Part 5.</td>
<td>Lecture by instructor: 2nd fourth of Part 5.</td>
</tr>
<tr>
<td>21</td>
<td>Students ask questions on Part 5.</td>
<td>Lecture by instructor: 3rd fourth of Part 5.</td>
</tr>
<tr>
<td>22</td>
<td>Short-answer type examination over Part 5 (30 min.); discuss examination over Part 5.</td>
<td>Lecture by instructor: last fourth of Part 5; take up problem assignments of Part 5.</td>
</tr>
<tr>
<td>23</td>
<td>First half of 50-item multiple-choice examination over Parts 3, 4, and 5.</td>
<td>First half of 50-item multiple-choice examination over Parts 3, 4, and 5.</td>
</tr>
<tr>
<td>24</td>
<td>Second half of 50-item multiple-choice examination over Parts 3, 4, and 5.</td>
<td>Second half of 50-item multiple-choice examination over Parts 3, 4, and 5.</td>
</tr>
<tr>
<td>25</td>
<td>Take up problem assignments of Part 6; hand out Part 7, with problem assignments of Part 7; instructor covers highlights of Part 6.</td>
<td>Lecture by instructor: 1st third of Part 6; hand out problem assignments of Part 6, due Period 27.</td>
</tr>
<tr>
<td>27</td>
<td>Short-answer type examination over Part 6 (30 min.); discuss examination over Part 6.</td>
<td>Lecture by instructor: last third of Part 6; take up problem assignments of Part 6.</td>
</tr>
<tr>
<td>Period</td>
<td>Note-Test Class</td>
<td>Lecture Class</td>
</tr>
<tr>
<td>--------</td>
<td>----------------</td>
<td>--------------</td>
</tr>
<tr>
<td>28</td>
<td>Take up problem assignments of Part 7; hand out Part 8, with problem assignments of Part 8; instructor covers highlights of Part 7.</td>
<td>Lecture by instructor: 1st third of Part 7; hand out problem assignments of Part 7, due Period 30.</td>
</tr>
<tr>
<td>29</td>
<td>Students ask questions on Part 7.</td>
<td>Lecture by instructor: 2nd third of Part 7.</td>
</tr>
<tr>
<td>30</td>
<td>Short-answer type examination over Part 7 (30 min.); discuss examination over Part 7.</td>
<td>Lecture by instructor: last third of Part 7; take up problem assignments of Part 7.</td>
</tr>
<tr>
<td>31</td>
<td>Take up problem assignments of Part 8; hand out Part 10, with problem assignments of Part 10; instructor covers most of highlights of Part 8.</td>
<td>Lecture by instructor: 1st fourth of Part 8; hand out problem assignments of Part 8, due Period 34.</td>
</tr>
<tr>
<td>32</td>
<td>Instructor completes highlights of Part 8; students ask questions on Part 8.</td>
<td>Lecture by instructor: 2nd fourth of Part 8.</td>
</tr>
<tr>
<td>33</td>
<td>Students ask questions on Part 8.</td>
<td>Lecture by instructor: 3rd fourth of Part 8.</td>
</tr>
<tr>
<td>34</td>
<td>Short-answer type examination over Part 8; (30 min.); discuss examination over Part 8.</td>
<td>Lecture by instructor: last fourth of Part 8; take up problem assignments of Part 8.</td>
</tr>
<tr>
<td>35</td>
<td>40-item multiple-choice examination over Part 6, 7, and 8.</td>
<td>40-item multiple-choice examination over Parts 6, 7, and 8.</td>
</tr>
<tr>
<td>36</td>
<td>Take up problem assignments of Part 10; hand out Part 11, with problem assignments of Part 11; instructor covers highlights of Part 10.</td>
<td>Lecture by instructor: 1st third of Part 10; hand out problem assignments of Part 10, due Period 38.</td>
</tr>
<tr>
<td>37</td>
<td>Students ask questions on Part 10.</td>
<td>Lecture by instructor: 2nd third of Part 10.</td>
</tr>
<tr>
<td>Period</td>
<td>Note-Test Class</td>
<td>Lecture Class</td>
</tr>
<tr>
<td>--------</td>
<td>----------------</td>
<td>--------------</td>
</tr>
<tr>
<td>38</td>
<td>Short-answer type examination over Part 10 (30 min.); discuss examination over Part 10.</td>
<td>Lecture by instructor: last third of Part 10; take up problem assignments of Part 10.</td>
</tr>
<tr>
<td>39</td>
<td>Take up problem assignments of Part 11; instructor covers most of highlights of Part 11.</td>
<td>Lecture by instructor: 1st fourth of Part 11; hand out problem assignments of Part 11, due Period 42.</td>
</tr>
<tr>
<td>40</td>
<td>Instructor completes highlights of Part 11; students ask questions on Part 11.</td>
<td>Lecture by instructor: 2nd fourth of Part 11.</td>
</tr>
<tr>
<td>41</td>
<td>Students ask questions on Part 11.</td>
<td>Lecture by instructor: 3rd fourth of Part 11.</td>
</tr>
<tr>
<td>42</td>
<td>Short-answer type examination over Part 11 (30 min.); discuss examination over Part 11.</td>
<td>Lecture by instructor: last fourth of Part 11; take up problem assignments of Part 11.</td>
</tr>
<tr>
<td>43</td>
<td>40-item multiple-choice examination over Parts 10 and 11.</td>
<td>40-item multiple-choice examination over Parts 10 and 11.</td>
</tr>
<tr>
<td>44</td>
<td>Hand Scale of Attitudes Toward College Courses.</td>
<td>Same.</td>
</tr>
<tr>
<td>45</td>
<td>Watson-Glaser Critical Thinking Appraisal.</td>
<td>Same.</td>
</tr>
</tbody>
</table>
Activities: Prior to consideration of this material in class, students are to study the text along with these mimeographed lecture notes; also, students are to hand in problem assignments given at the end of these notes before consideration of the content in class. It will be extremely helpful if students will utilize the many excellent overhead projectuals associated with Part III which are in the chemistry department (may obtain projector and projectuals from the instructor). Also, the use of chemical models, which may either be purchased from the book store or borrowed from the chemistry department, are excellent for assistance in study.

Three days will be devoted to Part III as follows: (1) instructor covers highlights and/or more difficult material; student questions are encouraged, (2) student request day, for consideration of more difficult material, (3) 30-minute short answer type examination, followed by discussion of the examination.

Content of Part III

I. Definition of chemical bond, p. 79.

II. Molecules, pp. 79-81.
   A. Definition from text: a molecule is an electrically neutral aggregate of atoms held together strongly enough to be considered as a unit (p. 79).
   B. Another definition: a molecule is the smallest part of an element or compound that has the properties of that element or compound.
   C. Comparison of the two definitions.
D. Examples of molecules.
1. Gaseous: $\text{H}_2, \text{O}_2, \text{F}_2, \text{CO}_2, \text{CO}, \text{NO}$, $\text{N}_2\text{O}$.
2. Liquid: $\text{H}_2\text{O}, \text{C}_8\text{H}_{18}$ (octane), $\text{C}_6\text{H}_6$ (benzene).
3. Solid: $\text{S}_8$ (sulfur), $\text{P}_4$ (phosphorous), $\text{CH}_3\text{CONH}_2$ (acetamide), $(\text{CH}_3)_3\text{COH}$ (tertiary butyl alcohol).

E. Existence of molecules listed above as solid, liquid, or gaseous, depending on temperature.

F. Formation of molecules from atoms.
1. Implies rearrangements of electrons.
2. Implies combination of atoms.
3. Implies more stable state (lower energy) when atoms combine than in the isolated state.

G. Theoretical approach to description of molecules.
1. Molecular orbital description.
3. Difference in the above two approaches, illustrated with hydrogen molecule and hydrogen chloride molecule.

III. Ionic bonds, pp. 81-82.
A. Definition: bonds in which electrons are completely transferred from one atom to another.
B. Relation of ionization potential and electron affinity to the ionic character of bonds.
C. Percent ionic character of bonds, according to Pauling.
D. Examples of formation of ionic bonds: sodium chloride ($\text{NaCl}$), potassium bromide ($\text{KBr}$).
E. Steps in formation of ionic bonds.
1. Energy required by metal (ionization potential).
2. Energy released by non-metal (electron affinity).
3. Energy released due to bonding together.
F. Electrons released and gained in bond formation.
1. One electron released by atoms in Group I (alkalies, including sodium and potassium).
2. Two electrons released by atoms in Group II (alkaline earths, including calcium and barium).
3. One electron gained by atoms in Group VII (halides, including chlorine and bromine).
4. Two electrons gained by atoms in Group VI (oxygen family, including oxygen and sulfur).
5. Examples of ionic substances formed from reactions of Group I or Group II atoms with Group VI or Group VII atoms.

G. Characteristics of ionic solids, e.g., melting points and conductivity.

IV. Covalent bonds, pp. 83-84.
   A. Definition from text: bonds in which electrons are shared between atoms.
   B. Examples of covalent bonds: \( \text{H}_2, \text{Cl}_2, \text{HCl} \), organic molecules composed of carbon and hydrogen (like methane, \( \text{CH}_4 \)).
   C. Diatomic molecules, especially the common ones: \( \text{H}_2, \text{N}_2, \text{O}_2, \text{F}_2, \text{Cl}_2, \text{Br}_2, \text{I}_2 \).
   D. Electronic symbols and charge distribution representations: show with \( \text{H}_2, \text{Cl}_2, \text{HCl}, \text{C}_2 \text{H}_2 \) (ethylene), \( \text{C}_2 \text{H}_4 \) (acetylene).

V. Polarity of bonds, pp. 85-88.
   A. Difference in polar and non-polar bonds: polar bonds (those in which positive and negative centers of charge do not coincide); non-polar (those in which positive and negative centers of charge coincide).
   B. Illustration of non-polar bonds: \( \text{H}_2, \text{Cl}_2 \).
   C. Illustration of polar bonds: \( \text{HCl}, \text{BrCl} \).
   D. Meaning of a dipole (a molecule or bond which has two centers of charge separated by some distance).
   E. Dipole moment: charge X distance between positive and negative centers.
   F. How a dipole acts in an electric field.
   G. Dielectric constant: ratio of condenser's capacity with a substance between plates to its capacity with a vacuum between plates.
   H. Prediction of polarity or non-polarity of a bond
   1. With two atoms.
      a. \( \text{CO}_2 \) is non-polar (why?).
      b. \( \text{H}_2\text{O} \) is polar (why?).
      c. \( \text{CCl}_4 \) is non-polar (why?).
      d. \( \text{CHCl}_3 \) is polar (why?).
VI. Electronegativity, pp. 88-90.
A. A definition: the tendency of an atom to attract shared electrons.
B. As a function of ionization potential and electron affinity.
C. Chart of electronegativities, p. 89.
D. Trends in electronegativities.
E. Usefulness.
   1. Predicting type of bonds.
   2. Predicting polarity of covalent bonds.

VII. How bond energies are used in setting up electronegativity values, pp. 90-92.
A. Definition: the bond energy is the energy required to break a bond and form neutral atoms.
B. Relationship to heats of reaction.
C. Bond energy of R₂ (103 kcal/mole = 17.1 × 10⁻²³ kcal/bond).
D. Bond energy for Cl₂ (57.2 kcal/mole = 4.75 × 10⁻²³ kcal/bond).
E. Bond energy for HCl (102 kcal/mole = 16.9 × 10⁻²³ kcal/bond).
F. How C, D, and E above tell something about differences in electronegativities.
G. Reference to Table, p. 91; rationalization of bond energies given.
H. Relationship between bond energies and dipole moments.

VIII. Valence and saturation of valence, pp. 92-96.
A. Definition of valence, as used in text: the ability of atoms to bind together.
B. Valence electrons of Na, Ca, Al, P, O, N.
   1. How the number of valence electrons helps determine the combining ratio of atoms.
   2. Determination of the formulas of nine possible binary compounds from the six elements above.
C. Accounting for saturation of valence in methane (CH₄) by sharing electrons and forming covalent bonds.
D. Accounting for saturation of valence in compounds of hydrogen with F, O, N.
E. Ammonium salts and saturation of valence.
F. Coordinate covalent bonds.
G. Saturation of valence in formation of \( \text{F}_2, \text{H}_2\text{O}, \text{H}_2\text{NNH}, \text{C}_3\text{H}_8, \text{C}_2\text{H}_4, \text{C}_2\text{H}_2, \text{C}_6\text{H}_6 \).

H. Single, double, and triple bonds in organic molecules.

I. Violation of the octet rule.

IX. Resonance, pp. 96-97.
   A. Definition, p. 97: resonance is described as a situation in which no single electronic formula conforms both to observed properties and to the octet rule.
   B. Resonance does not imply a resonating or oscillating situation.
   C. Examples of resonance: \( \text{SO}_2, \text{C}_6\text{H}_6 \) (benzene), \( \text{N}_2\text{O} \) (nitrous oxide).

X. Shapes of molecules (use models to investigate), pp. 97-101.
   A. Water (sp\(^3\) hybridization).
   B. Methane (sp\(^3\) hybridization).
   C. Ethene (sp\(^2\) hybridization).
   D. Ethyne (sp hybridization).
   E. Ammonia (sp\(^3\) hybridization).

XI. Problem assignments, pp. 100-102.
   A. For average insight; to be handed in by all students prior to consideration of related material in class: 4.6, 4.10, 4.12, 4.13, 4.14, 4.15, 4.16, 4.17.
   B. For deeper insight; may be handed in prior to consideration of related material in class: 4.19, 4.20.
   C. For deepest insight: may be handed in prior to consideration of related material in class: 4.18, 4.22.
### TABLE XXI

**DEVIATION FROM SUMS OF SQUARES AND CROSSPOINTS FOR SOURCES OF VARIATION, MCTOT AS CRITERION**

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>$y^2$</th>
<th>$x_1^2$</th>
<th>$x^2$</th>
<th>$x_1y$</th>
<th>$x_2y$</th>
<th>$x_1x_2$</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>MCTOT</td>
<td>ACT</td>
<td>WGRP</td>
<td>ACT-MCTOT</td>
<td>WGRP-MCTOT</td>
<td>ACT-WGRPR</td>
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<tr>
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<td>.4917272E 5</td>
<td>.1251699E 4</td>
<td>.5762125E 4</td>
<td>.5105836E 4</td>
<td>.1153409E 5</td>
<td>.1863250E 4</td>
</tr>
<tr>
<td>Method</td>
<td>.5314698E 1</td>
<td>.1923767E 2</td>
<td>.1805864E 3</td>
<td>-.1011541E 2</td>
<td>-.3098340E 2</td>
<td>.5894226E 2</td>
</tr>
<tr>
<td>Level</td>
<td>.2150781E 5</td>
<td>.7985757E 3</td>
<td>.4153875E 3</td>
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<tr>
<td>Interaction</td>
<td>.2830060E4</td>
<td>.5904542E 0</td>
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<td>.1042248E 3</td>
<td>.3604785E 2</td>
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<tr>
<td>Within</td>
<td>.2482953E 5</td>
<td>.4333555E 3</td>
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<td>.1045008E 4</td>
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### TABLE XXII

**DEVIATION FROM SUMS OF SQUARES AND CROSSPRODUCTS FOR SOURCES OF VARIATION PLUS WITHIN, MCTOT AS CRITERION**

<table>
<thead>
<tr>
<th>Within Plus</th>
<th>$y^2$</th>
<th>$x_1^2$</th>
<th>$x^2$</th>
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<th>$x_1x_2$</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>MCTOT</td>
<td>ACT</td>
<td>WGRP</td>
<td>ACT-MCTOT</td>
<td>WGRP-MCTOT</td>
<td>ACT-WGRPR</td>
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<tr>
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<tr>
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<td>.1160112E 5</td>
<td>.1881375E 4</td>
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<td>Interaction</td>
<td>.2765959E 5</td>
<td>.4339459E 3</td>
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<td>.1149224E 4</td>
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<td>.1088989E 1</td>
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</tbody>
</table>
### TABLE XXIII

**deviation form sums of squares and crossproducts for sources of variation, acspt as criterion**

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>$y^2$</th>
<th>$x_1^2$</th>
<th>$x_2^2$</th>
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<th>$x_2y$</th>
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</thead>
<tbody>
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<td></td>
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<td>ACT</td>
<td>WGRPR</td>
<td>ACT-MCTOT</td>
<td>WGRPR-MCTOT</td>
<td>ACT-WGRPR</td>
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<td>.5762125E 4</td>
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<tr>
<td>Method</td>
<td>.4396739E 2</td>
<td>.1923767E 2</td>
<td>.1805864E 3</td>
<td>-.2909099E 2</td>
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<td>.1803422E 4</td>
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<td>.3186890E 1</td>
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<tr>
<td>Within</td>
<td>.5678934E 4</td>
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<td>.1682562E 4</td>
<td>.3109336E 3</td>
<td>.6854063E 3</td>
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</tbody>
</table>

### TABLE XXIV

**deviation form sums of squares and crossproducts for sources of variation plus within, acspt as criterion**

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<td></td>
<td>MCTOT</td>
<td>ACT</td>
<td>WGRPR</td>
<td>ACT-MCTOT</td>
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<tr>
<td>Level</td>
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<td>Interaction</td>
<td>.6215845E 4</td>
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<td>.1520601E 4</td>
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<td>.7612429E 3</td>
<td>.8858643E 0</td>
</tr>
</tbody>
</table>
### TABLE XXV

DEVIATION FROM SUMS OF SQUARES AND CROSSPRODUCTS FOR SOURCES OF VARIATION, WGPL AS CRITERION

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>$y^2$ MCTOT</th>
<th>$x_1^2$ ACT</th>
<th>$x_2^2$ WGP</th>
<th>$x_1y$ ACT-MCTOT</th>
<th>$x_2y$ WGP-MCTOT</th>
<th>$x_1x_2$ ACT-WGP</th>
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<td>Method</td>
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<td>.8886238E 2</td>
<td>.2722883E 3</td>
<td>.5894226E 2</td>
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<td>Level</td>
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<td>.3980812E 4</td>
<td>.1794562E 4</td>
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<tr>
<td>Interaction</td>
<td>.1892114E 3</td>
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<td>-.2162883E 3</td>
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### TABLE XXVI

DEVIATION FROM SUMS OF SQUARES AND CROSSPRODUCTS FOR SOURCES OF VARIATION PLUS WITHIN, WGPL AS CRITERION

<table>
<thead>
<tr>
<th>Within Plus</th>
<th>$y^2$ MCTOT</th>
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<th>$x_2^2$ WGP</th>
<th>$x_1y$ ACT-MCTOT</th>
<th>$x_2y$ WGP-MCTOT</th>
<th>$x_1x_2$ ACT-WGP</th>
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</thead>
<tbody>
<tr>
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<td>.1236691E 4</td>
<td>.5746750E 4</td>
<td>.1958797E 4</td>
<td>.4806750E 4</td>
<td>.1876906E 4</td>
</tr>
</tbody>
</table>
The Note-Test Method, as Described
by Professor Trahanovsky*

Period 1: Before this period the student receives a set of memotographed lecture notes (called a "part") which covers material that would take approximately three normal lectures to deliver. The material in the part corresponds quite closely to the text and contains only little new material or references to outside readings. Problems from the text that the student should work are also listed in the part. The part is designed to highlight the important points of the text and make the reading of the text easier for the student. During Period 1, the instructor covers the highlights of the part often using demonstrations to convey or illustrate important points. The instructor assumes that the student has read the part and studied the text in order to understand the material that the part outlines. Questions from the students are also answered during this period, and the instructor feels no obligation to cover all the important points in the part since the material is adequately covered by the part and text.

Period 2: This period is a question session. Students ask questions (verbal or written) based on the part, the test, and the problems. The instructor can use certain questions as a starting point for a more elaborate discussion when he feels it necessary. In order to ensure a lively question session, the instructor can ask questions of various class members picked at random if the students have no questions (this has never occurred in my experience).

Period 3: During the first 30 minutes of this period a 50-point written examination is given covering the material outlined by the part. The last portion of this period is used to discuss the examination and a new part is handed out.

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