A STUDY OF STUDENT ACHIEVEMENT IN HIGH SCHOOL CHEMISTRY USING CHEM STUDY AND CONVENTIONAL APPROACHES

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PREFACE

Recent investigation into the content and organization of the chemistry curriculum is causing a revision in the traditional program of chemistry teaching in the secondary schools of the United States. Many school administrators are facing the problem of introducing some phase of the new chemistry into their educational programs. Many are reluctant to incorporate new courses into the curriculum until there is statistical evidence establishing the superiority of the new materials over those currently offered.

The purpose of the study is to find experimental evidence of the relative merits of the CHEM Study approach compared with the conventional approach of teaching first year high school chemistry.

During the preparation of this paper, many individuals have contributed personal and professional assistance. Throughout the activity of the study as well as in professional growth in this research project, the counsel, consideration, and patience of Dr. Henry P. Johnston, advisory committee chairman, is gratefully acknowledged. A parallel debt of gratitude is also due to the other members of the advisory committee: Dr. R. E. Sweitzer, Dr. Paul Arthur, and Dr. T. E. Moore.

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

CHAPTER I

BACKGROUND OF THE STUDY

The attitude of the American people toward science during the past half century has changed markedly. Whereas science had previously been looked upon as an adjunct to other studies, during this time it has reached a place of prominence of no mean calibre. That scientific education was necessary for industrial progress was advocated during the 19th century (1). The general public, however, was not yet captivated by the possibilities of science. The trend toward the respect for science had reached such a point by 1954 that a noted writer wrote: "The modern world is the world of modern science. No part of life has escaped its influence, and it has transformed what it has touched (2)."

The attitude of American society toward science is changing also because there is an increasing tempo of scientific progress (3). Strong and Benfey (4) have estimated that the amount of chemical information has doubled about every thirteen years during the last quarter century. As new information is discovered it tends to accelerate the process and so becomes somewhat self-propagating. Each new gain supplies the means for the next (5). This is undoubtedly a result of several factors. New tools are continually being devised and these tend to increase the rate of progress. Methods of conducting research are being constantly improved. Discoveries working toward the public benefit generate added public support for further research. Finally, with the addition of scientific facts, there is much greater chance that proper combinations of data will bring new scientific advance. A suggestion has been made that the theoretical limit to the rate of scientific progress may increase exponentially with the scientific knowledge available (6). Whether this is true or not remains to be seen, but everyone is aware of the increasing scientific knowledge.

In light of the changing attitudes of American society toward science, modifications will occur in the goals and methods used in education.

Change in the American educational system comes slowly. Two of the main reasons for this lag in the acceptance of new ideas in the curriculum are the problems of educating the public to the changing needs and purposes of education and, perhaps the primary reason, the reluctance of both teachers and administrators to accept the necessity for change in the educational program.

Recently much has been written concerning the need for more effective chemistry instruction at all levels of education. If new methods have been developed which will impart a better understanding of chemical concepts and result in greater achievement on the part of most pupils, these methods should be used.

Many high schools in this country have a satisfactory course in chemistry. However, in many instances the high school course is extremely low in quality and out of touch with the science of chemistry as it is known professionally. Most high school chemistry courses have a characteristic discussion of too many topics resulting from the accumulation of new material and the unwillingness of most authors to reject any material that was ever in the course. Also, there is a tremendous amount of modern technical information missing in most of these high school chemistry courses. Saddest of all is the movement away from laboratory experience, probably the most important part of the course to the average chemistry student.

However, there are many examples of a progressive change for the better, including participation of the American Chemical Society nationally and through its local sections. The American Chemical Society since its establishment has had an interest in high school chemistry. In 1959 the society formed a committee with Professor A. B. Garrett of Ohio State University as chairman to examine and criticize the purpose and content of high school chemistry courses.

Partially as a result of the recommendations of this committee the National Science Foundation decided to sponsor two studies of high school chemistry courses. The earlier study is known as the "Chemical Bond Approach" and is directed by Professor Lawrence E. Strong of Earlham College, Richmond, Indiana. The second study is called "Chemical Education Materials Study"[1] and is directed by Professor J. Arthur Campbell of Harvey Mudd College, Claremont, California. These two studies are part of the series of high school science projects sponsored by the National Science Foundation which includes Physical Sciences Study, School Mathematics Study, Biological Sciences Curriculum Study, and Teaching Resources Development in Geology Study (7).

The CHEM Study course and the CBA Course have now been in actual operation for four and five years respectively. The CHEM Study course during the past three years has contributed to the education of over 150,000 high school students (8).

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[1]Hereinafter designated as CHEM Study.

Statement of Problem

Recent investigation into the content and organization of the chemistry curriculum is causing a revision in the traditional program of chemistry teaching in the secondary schools of the United States. Many school administrators are facing the problem of introducing some phase of the new chemistry into their educational programs. Many are reluctant to incorporate new courses into the curriculum until there is statistical evidence establishing the superiority of the new materials over those currently offered.

Any suggested curriculum revision inevitably and quite properly raises questions as to what losses and gains may result from such a revision. Today there is an urgent need for statistical research based upon results obtained from evaluation of chemistry programs in which the new materials are in current use.

Purpose of the Study

In contemplating any curriculum change in the public schools of America, a school administrator must be reasonably sure such a change, if made, will not work to the detriment of the students involved. Thus, in making a change in the chemistry curriculum from conventional chemistry to one of the new chemistry programs currently offered, a school administrator must be reasonably sure that the students under his supervision will receive course content which will result in student achievement equal or superior to achievement made through study of the material replaced.

The purpose of the current study is threefold. The study will be undertaken to present experimental evidence at the high school level which might help to 1) determine if student achievement in the CHEM Study course in chemistry is equivalent to student achievement in a conventional course in chemistry, 2) discover what relationship exists between student grade level and instructional method in chemistry when compared on the basis of student achievement, and 3) provide information which could be used by teachers, school administrators, parents, and interested citizens in making their own evaluations of the CHEM Study method of teaching chemistry.

Student achievement, as it is related to the study, will encompass three areas in chemical thought. These are as follows: 1) Recall of Information, which tests recall of definitions of important terms, acquaintance with important concepts, and general knowledge of physical and chemical properties of common elements and their compounds; 2) Application of Principles, which tests the ability of a student to apply various important principles and theories of chemistry in making simple predictions; and 3) Quantitative Application of Principles, which is concerned with skills such as balancing equations, applications of gas laws, determination of molecular weights, the quantitative aspects of electrolysis, and fundamental problems in stoichiometry.

Plan of the Study

Design

Achievement data for the study will be obtained from the scores made on the High School Chemistry; American Chemical Society - National Science Teachers Association Cooperative Examination, Form 1961[2] by

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[2]Hereinafter designated as ACS Examination.

21 classes of students being taught conventional chemistry and by four classes of students studying a course prepared by CHEM Study. The raw scores from the quantitative thinking and composite score sections of the Iowa Test of Educational Development for the students, used in a matched paired design, will be used as the measure of their pre-chemistry ability and intellectual maturity.

Data included in this study will be treated under two statistical designs in an attempt to obtain information relative to the stated purposes of the study. These two designs will be 1) the method of equivalent groups, matching by pairs, using single classification analysis of covariance (9), and 2) the t-test for significance between means (10).

Under the equivalent groups design, each pair of students will be matched on the basis of grade level and the scores received on the quantitative thinking and composite score sections of the Iowa Tests of Educational Development. This battery of achievement tests will be administered early in October of the eleventh grade year. One member of each matched pair will be taught the first course in chemistry from CHEM Study materials. His counterpart will receive his training in the first year of chemistry in a class featuring conventional materials.

The scores obtained on the Iowa Tests of Educational Development represent a reliable measure of the mathematical background and intellectual potential of each student prior to his chemistry experience (11).

In September, at the beginning of the 1962-63 school year for each student, Part I of the ACS Examination will be administered to each first year chemistry student.[3] The following May Part II of the ACS Examination will be administered to each first year chemistry student completing the course.[4] The raw scores made on these tests will become the basis for the comparison of achievement made by students included in the study.

For statistical purposes these data will then be arranged in a single classification analysis of covariance matched pair design. In this design there will be two methods of instruction in first year chemistry, CHEM Study and conventional method.

The students included in the second phase of the study will represent all students in both CHEM Study and conventional first year chemistry groups for which both grade level and achievement test scores are available. The t-test for significant difference between means will be used to compare student achievement between grade levels.

Analysis of the Data

The raw scores received on the pre- and post- achievement test will be used as the measure of achievement in first year chemistry for each member of the set of matched pairs.

The term "achievement score," as used in the t-test analysis, will be taken as the difference between what the student made on his pre-test and post-test ACS Examination scores.

The achievement data for the matched pairs of chemistry students

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[3]Hereinafter designated as pre-test.

[4]Hereinafter designated as post-test.

will be analyzed to give the following information: 1) A preliminary analysis of variance of the pre-test scores to test the successfulness of the random assignment of students to the two groups, 2) an analysis of covariance to determine the relationship of chemistry achievement to type of chemistry taught, and 3) the coefficient of correlation between and within groups to determine their relationship.

For the t-test analysis the achievement data recorded for each grade level will be grouped according to CHEM Study or conventional chemistry teaching methods. The mean raw score, the difference between means, and the t-test value will be calculated for both groups by grade level from the raw scores in each group.

Scope of the Study

The study will be limited to student achievement in the first course in chemistry at North, East, South, and Southeast High Schools, Wichita, Kansas. The population from which the samples will be drawn will include all tenth, eleventh, and twelfth grade students who will have completed both the Iowa Tests of Educational Development taken in October at the beginning of their eleventh grade year and the pre- and post- test of the ACS Examination.

The students who will comprise the experimental group studying the first course in chemistry prepared by CHEM Study will be regularly enrolled tenth, eleventh, and twelfth grade students during the 1962-63 school term. They will be members of four heterogeneously grouped chemistry classes taught by four experienced teachers who have received additional training in teaching CHEM Study materials at a National Science Foundation Summer Institute.

The students who will be included in the control group will study a conventional course in first year chemistry. They will be members of 21 heterogeneously grouped chemistry classes taught by five teachers during the 1962-63 school term. Four of the five teachers participating in the study will be teaching both conventional chemistry and CHEM Study prepared materials.

The environmental background of all students included in the study will be that found in a city of about 260,000 people which is the business and cultural center for a prosperous, industrially and agriculturally oriented community. Communication media for the community include four daily newspapers, nine radio stations, and three television stations.

The school system is organized along the 6-3-3 plan and is excellently staffed, adequately supplied, and progressively administered.

Hypotheses Tested

The hypotheses for this study, stated in null form, are:

At the .05 level of confidence, there will be no significant difference in achievement as measured on a nationally standardized high school chemistry achievement test in first year chemistry at the high school level between the following groups:

1. Two equivalent groups of first year chemistry students, when the members of one group were taught from materials prepared by CHEM Study and the other group of students were taught from a conventional text.

2. One group of students taught first year chemistry from CHEM Study materials and one group of students taught first year chemistry from a conventional text when students are grouped according to grade levels (tenth, eleventh, and twelfth).

3. Tenth, eleventh, and twelfth grade levels when compared within instructional method (CHEM Study or conventional chemistry).

Summary

Recently much has been written concerning the need for more effective chemistry instruction at all levels of education. An attempt is being made by professional groups to change the scope and content of the chemistry courses currently taught in the high schools of the United States.

Professional educators are facing the problem of introducing some phase of the new chemistry into their curricula. Many school administrators are reluctant to replace traditional courses with new ones unless there is satisfactory evidence establishing the superiority of the new materials over the traditional ones.

The purpose of the study is to find experimental evidence of the relative merits of the CHEM Study approach compared with the conventional approach of teaching first year chemistry. The progress of students will be studied to 1) determine if student achievement in the first course in chemistry prepared by CHEM Study is equivalent to student achievement in conventional first year chemistry, 2) discover what relationship exists between student grade level and instructional method in chemistry when compared on the basis of student achievement, and 3) provide information which may be used by teachers, school administrators, parents, and interested citizens in making their own evaluations of the first course in chemistry prepared by CHEM Study.

The plan of this study is based upon two statistical designs. These are an equivalent group, matched pair design, using single classification analysis of covariance, and the t-test for significant differences between means.

The Iowa Tests of Educational Development will be administered to all students in the Wichita High Schools, Wichita, Kansas, at the beginning of their eleventh grade school terms. Those students studying CHEM Study first year chemistry will be equated with the students studying a conventional course in first year chemistry using grade level and the quantitative thinking and composite score sections of the Iowa Tests of Educational Development as the basis of matching pairs.

The relationship of student achievement in first course in chemistry for the students taught from CHEM Study prepared materials and the students taught a conventional course will be statistically analyzed by the analysis of covariance.

The relationship of student achievement between CHEM Study and conventionally taught groups as compared on the basis of grade level--tenth, eleventh, or twelfth--will be statistically analyzed by the t-test for significance.

The ACS Examination pre-test will be administered to all first year chemistry students in September of the 1962-63 school term. The ACS Examination post-test will be administered to all first year chemistry students in May of the 1962-63 school term. The raw scores of achievement for the set of matched pairs of first year chemistry students will be statistically analyzed by means of the single classification analysis of covariance and statistical inferences for the null hypothesis, at the .05 level of confidence, will be drawn.

In an attempt to provide information regarding student achievement in first year chemistry relative to method of instruction and grade level, the t-test analysis will be completed for the CHEM Study and the conventional first year chemistry students, and statistical inferences for the null hypothesis at the .05 level of confidence will be drawn.

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CHAPTER II

HISTORICAL REVIEW

Since the end of World War II there has been a definite shift of the American industrial economy into the sophisticated engineering exploitation of advanced scientific knowledge. This change has every indication of increasing at an accelerating rate. Probably the largest stimulating factor for this stems from the precise and exacting requirements of the military preparedness program. However, this program has also given birth to new technology which has had a widespread impact of supreme importance on the nonmilitary economy as well.

In our world of today the person who wishes to understand the industrial world or to provide technical leadership of significant importance to this industrial world must have a dominating control of scientific principles far greater than was required in the past. Also, this mastery of scientific principles must be a true and definite knowledge of today's science and engineering. New ideas and applications are constantly replacing the old and a person must always be prepared to adapt to new ideas if he is to keep up with the technological progress of the future.

These changes which have taken place in the past twenty years have strongly effected the man in the working force. Today the tools he uses and the tasks he performs require more knowledge of arithmetic, mathematics, and elementary scientific principles than ever before. In fact, we have the lowest percentage of unskilled labor today than at any other time in our history. Also, there is a large percentage of the traditional skilled trades giving up their jobs for white collar or more technical jobs.

In short, there is one definite prerequisite for success in today's political, economical, technical, and scientific world: Education. Whether it be a high school, trade school, or college education, a person is handcuffed without a general knowledge of the world in which he lives.

In the October 17, 1960, issue of Chemical and Engineering News, Dr. Glenn T. Seaborg, Chancellor of the University of California, gave this definition of the liberally educated man:

> My definition of a liberally educated person is one who is aware of the nature of his physical and social environment and of his own nature; who understands the origins of the world's social, religious, governmental, and political institutions, and the ideas upon which they are based; and who, because of this knowledge, has some basis for making intelligent decisions to adjust to his environment or to change to a better one.

Dr. Seaborg believes that such a definition means that scientific studies form a vitally important part of a liberal education. "The educated man of today can no more ignore science than his predecessor in the Middle Ages could ignore the Christian church or the feudal system (1)."

Dr. Seaborg's analysis of trends in today's American life leads to the conclusion that one rigid test of the quality of the American educational system is its success in providing adequate and proper scientific instruction for those seeking a broad education, for those seeking specialized technical training, and for those seeking merely occupational training at the high school or junior college level. In the past few years several fateful events have generated a growing awareness of the supreme importance of education or national survival and have instigated an unparalleled re-examination of the entire school system, particularly instruction in science.

Sometime between 1750 and 1800 chemistry was first introduced into university medical schools and just previous to 1800 chemistry was taught in the senior year in a few colleges. As the knowledge of chemistry grew and as the various divisions such as general, organic, and qualitative were made, elementary chemistry moved down until finally it became a freshman course. In the early 19th century chemistry found its way into the high school curriculum because of the rapid growth of interest in chemical studies. This new interest was caused in part by popular demonstration lectures and the results of practical research (2).

There are many ways to teach chemistry. Past courses have been enormously varied; present courses explore many methods; and future courses are being planned with considerable care in many localities. Yet widespread discontent exists among secondary school chemistry teachers, even those who are giving the most thought to planning improvements in their courses (3). It has been the consensus of opinion that chemists should explore and examine several of these ways to teach chemistry. This is the reason for the existence of both the Chemical Bond Approach and Chemical Education Materials Study groups, and their interest in working with other experimental programs in chemistry. "The intent, however, is not to produce a single 'best' chemistry course. Rather to try out ideas and make it easy for others to adopt and adapt from them. Chemistry courses certainly should, and doubtlessly will, continue to differ in details. The main purpose of the present studies is to investigate major concepts and emphases, to base a high school course upon them, and to determine the feasibility of the resulting material (4)."

A Brief History of CHEM Study

In 1958 a committee was appointed by the American Chemical Society for the sole purpose of studying the possibility of revising the high school chemistry course. Dr. Alfred Garrett, Chairman of the Chemistry Department at Ohio State University, was named chairman of the committee. The committee consisted of college professors of chemistry and a high school chemistry teacher. After much deliberation, the committee recommended that a revision be made of the high school chemistry course and suggested generally what the course should contain. With Dr. Glenn T. Seaborg, Chancellor of the University of California, as chairman of the revision program and Dr. J. A. Campbell of Harvey Mudd College as director of the project, a Steering Committee was appointed which consisted of college professors, high school teachers, and other specialists.

The first meeting of the Steering Committee was held in January, 1960, at the University of California in Berkeley. At this meeting, the Steering Committee proposed the following:

1. A decision to write a text in the summer of 1960 rather than waiting another year was made. Dr. George Pimentel, University of California, would direct the project.

2. The course should be new, emphasizing principles,

theories, and understandings in chemistry. Descriptive chemistry would be woven into the course as examples to illustrate the principles. The course should be linked directly with the laboratory, thus demonstrating chemistry as an experimental science.

3. Laboratory experiments should be developed. These should be of a new open end type of experiment which will be integrated with the text. They should illustrate the principles and not be of the 'cookbook' type. It was established that two-period laboratory sessions be inaugurated if possible.

4. Films should be made which would explain, illustrate, and demonstrate, principles and subjects which cannot be easily presented in the classroom.

5. Monographs should be written by specialists in the various areas of chemistry in order to supplement the textual material and to further the interest and depth of the gifted student. These should be written in conjunction with a professional writer to obtain clearness of presentation.

6. Other areas of investigation were suggested. Among these are teaching machines, film strips, models, kits, etc. (5).

The general objectives proposed at this first meeting of the Steering Committee were to develop new teaching materials for high school chemistry courses, including a textbook, laboratory experiments, a laboratory manual, films, and supplementary reading materials. The specific objectives of the study are:

1. To diminish the separation between scientists and teachers in the understanding of science.

2. To stimulate and to prepare those high school students whose purpose it is to continue the study of science in college as a profession.

3. To encourage teachers to improve their teaching methods by studying chemistry courses which are geared to keep pace with the advancing scientific frontiers.

4. To further, in those students who will not con-

> tinue the study of chemistry after high school, an understanding of the importance of science in current and future human activities (6).

During the early part of the summer of 1960, nine college and university professors and nine high school teachers were assembled for a six weeks writing session at Harvey Mudd College. This writing committee was led by Professor G. C. Pimentel of the University of California. The high school teachers had the additional task of keeping the college and university professors "down to earth." Laboratory experiments were developed concurrently during the session by a staff headed by Professor Lloyd E. Malm, University of Utah.

This six weeks writing session produced a rough draft of a text of a high school chemistry book and an outline of laboratory experiments for trial use in a few high schools during the 1960-61 academic year.

The first nine chapters of the text were multilithed and made available to a group of 14 teachers from the San Francisco Bay area, nine teachers from the southern California area, and one other teacher from the New York City area. These teachers studied the material for four weeks on the campus of Harvey Mudd College in August, 1960. They performed all the experiments involved in the first half of the text.

The first editions of the text book and laboratory manual were then used during the 1960-61 school year in 23 high schools and one junior college by about 1,300 students. Weekly staff meetings were then held with the "pioneering" teachers during this first trial year.

Plans were then made, during the spring of 1961, to expand the program to include groups of teachers. Then in the summer of 1961, two Summer Science Institutes were conducted for chemistry teachers, one at Harvey Mudd College and the other at Cornell University. Both institutes were under the protection of the National Science Foundation. "Attending these two summer institutes were 58 teachers, who, with the 'veteran' teachers and 'solo' teachers would teach CHEM Study to 11,50C students (7)." In September of that year, revised editions of the text and laboratory manuals were available along with copies of the teacher's guide. Six films were also released during 1961.

Conferences were then held in January of 1962 at Berkeley and in June of 1962 at Claremont. These conferences provided more information for the third trial edition.

Again, summer institutes were planned for 1962 at eight colleges and were attended by 320 teachers. Six new centers and directors were then established. During the academic year of 1962-63, 550 schools were using the CHEM Study program and it was taught to 45,000 students in 46 states. Near the end of 1962, two new films were added and more were in the final stages of production.

During the academic year of 1962-63, final revisions of each section of the text, laboratory manual, and teacher's guide were made. Regular "hard back" books were made available in the fall of 1963. Also, scientific supply houses have developed charts and demonstration equipment for use in the CHEM Study course.

The real story of progress with the program comes by taking a close look at what was outlined for this course of study in the spring of 1960 and then comparing it with the program as it is today. "The sequence of topics is being knit together into a well correlated whole;

and explicit in all consideration for change and revision is the underlying basic assumption that this is 'an experimental science'; therefore, the laboratory program is to provide the student with his first look at a new topic (8)."

A fairly accurate progress report can be obtained by comparing and noting the difference between the first nine chapter headings of the trial text of 1960 and the current 1963-64 text.

Chapter Headings for Trial Text

I.	Chemistry: An Experimental Science
II.	Introduction to Atomic Theory
III.	Atoms Combined in Substances
IV.	Chemical Reactions and Phase Changes
V.	The Gas Phase: Kinetic Theory
VI.	Substances and Solutions
VII.	Chemistry and the Periodic Table
VIII.	Geochemistry: The Earth as a Source of Material
IX.	A General View of Chemical Reactions (9).

Chapter Headings for Current Text

I.	Chemistry: An Experimental Science
II.	A Scientific Model: The Atomic Theory
III.	Chemical Reactions
IV.	The Gas Phase: Kinetic Theory
V.	Liquids and Solids: Condensed Phases of Matter
VI.	Structure of the Atom and the Periodic Table
VII.	Energy Effects in Chemical Reactions
VIII.	The Rates of Chemical Reactions
IX.	Equilibrium in Chemical Reactions (10).

First, it is easily seen from the chapter headings of the first nine chapters of both revisions that the course is rightly entitled "CHEMISTRY - An Experimental Science." This continues to be the main thought that the text builds upon and has remained the subject of the beginning chapter of the text since its trial edition. The second chapter, however, has undergone quite some change. The current text introduces the atomic theory via the scientific model. It goes into quite some detail concerning the implications and growth of a scientific model and how it is useful to the scientist. The current text explains the scientific model concept by building its own model concerning the behavior of gases. Also, the 1963 edition has combined chapters II and III of the trial text into one under the heading of "A Scientific Model: The Atomic Theory."

The current text also has taken a new and different approach to the periodic table. It uses the scientific model of the atomic theory that was established in chapter II. The text uses the scientific model to explain the structure of the atom, and thus to introduce and explain the periodic table.

Chapter VIII of the trial text has been almost completely done away with. The current text has taken the most important facts from this chapter and combined it into one chapter concerning the chemistry of earth, the planets, and the stars. The current text has also expanded its discussion of chemical reactions. It now contains three chapters concerning energy effects, equilibrium, and rates of chemical reactions.

The persons responsible for "CHEMISTRY - An Experimental Science" firmly believe that science is limited and bounded by scientific changes and technical discoveries. As the science of chemistry changes and adds to itself, so must the high school chemistry course. The comparisons cited above serve as sufficient evidence to prove that the CHEM Study project advances with scientific improvements and that "CHEMISTRY - An Experimental Science" is as progressive as a high school chemistry course could possibly be.

CHEM Study and CBA Effects on Achievement in Chemistry

The CHEM Study course and the CBA course have now been in actual operation for four and five years respectively. It should be interesting to note how well students taking these new courses do on tests designed for the traditional chemistry course, or traditional chemistry curriculum.

One approach to answering this question was made during the 1961-62 academic school year (11). Experimental students, those taking either the CBA or the CHEM Study course, were to take finals designed for them and also a traditional chemistry achievement test. Also, a control group was established that was composed of students who were to take the traditional test and also one or the other of the experimental finals.

The CHEM Study group was composed of 7,000 students and 87 teachers. The CBA group was composed of 6,300 students and 69 teachers. Two groups of control students were then chosen to match the two experimental groups, these groups being randomly selected.

All students, both experimental and control, took the following tests: 1) The School and College Ability Test, Form 1A, parts I and II. This test, often referred to as SCAT, is a measure of scholastic ability; Part I consists of 30 sentence-completion items, and Part II of 25 numerical computation items. 2) The Cooperative Chemistry Test, Form Z, 81 items. The publisher's catalog states that this test "covers the material taught in most high school chemistry courses. . ." 3) Either the CHEM Study or the CBA final examination. Both experimental courses offer a comprehensive final, written by people closely associated with the course and based directly on the text and laboratory guide.

The SCAT test was given early in the school year; the other two tests were given near the end of the school year.

Between the experimental and control groups, four comparisons were planned. Two of the comparisons involved the CHEM Study students and two involved the CBA students. A plan was devised to compare each study by 1) the achievement of the experimental and control groups on the experimental test, and 2) the achievement of the two groups on the traditional test. The following table lists the results of this testing and evaluation program.

	Average Scores on SCAT test	Average Scores on Cooperative Chemistry test	Average Scores on Final Test Designed for Each Study
CHEM Study Group	37.0	31.9	25.7
Control Group A	37.0	37.7	13.1
CBA Group	38.0	34.3	25.8
Control Group B	37.9	38.1	15.6

It is easily seen from the table that there was virtually no difference between the experimental and the control group on average SCAT scores. In fact the results were extremely similar in every instance where the groups were compared. CHEM Study and CBA students scored higher than the corresponding control group students on the tests which were designed for the experimental courses, and control group students scored higher on the basis of the tests designed for traditional courses.

Utilization of CHEM Study Materials in Other Countries

Since its beginning in 1960, the work of CHEM Study has been the object of considerable interest on the part of chemists and educators in other countries (12). For the first three years, the CHEM Study staff dispensed information freely in response to numerous requests, but deferred consideration of requests for permission to translate until the course materials were published in difinitive form. Mindful that its materials and general approach would not necessarily meet the need or fit the organization of foreign educational systems, the Study has not taken the initiative in matters of foreign utilization.

The English language edition of the course materials is coming into widespread use in western Canada and in India.

The Study has authorized or is in the process of authorizing translations of the textbook into Chinese, Japanese, Portuguese, Spanish and Turkish.

Reactions of Teachers and Students

The CHEM Study has, from its outset in 1960, gone to considerable lengths to gather "feedback" from teachers and students using its course materials. For the first two years, this was done primarily through frequent area meetings at which the teachers reported and discussed their classroom experience with the course, the difficulties encountered by their students, and the ways in which they felt the materials should be modified. It can truthfully be reported that while these teachers and their students were not hesitant to criticize and discuss their problems frankly, their over-all reaction was one of strong enthusiasm for the new approach (13). During 1962-63 the course materials were used in 550 schools of all types by 700 teachers and 45,000 students. Information continued to be gathered from these teachers through area meeting, correspondence, questionnaires, and examination results, as the course materials were put into "final" form.

In January, 1963, a questionnaire was sent to all of the 700 teachers then using the course materials. About 400 of the teachers responded.

These responses were rather subjective, and perhaps the only thing they established conclusively was that the great majority of responding teachers who have tried the new approach like it (14).

College Courses and Entrance Examinations

No systematic follow-up study has yet been possible to determine the effect of the CHEM Study course on students' achievement in college chemistry courses (15). The reason is that really substantial numbers of these students first reached the colleges in the fall of 1963. Such limited informal inquiries as have been made suggest that CHEM Study-prepared students probably have a substantial advantage over conventially prepared students in an up-to-date freshman chemistry course.

There is evidence, on the other hand, that CHEM Study students were at a disadvantage on the College Entrance Examination Board chemistry examinations administered during 1961-1963. The average handicap was apparently somewhere between twenty and eighty points, and some evidence suggests that the best students were handicapped the most.

The discrepancy is easily accounted for. The CEEB examinations have been primarily designed for students who have taken a traditional chemistry course. The exams test on many specific subjects usually taught in "conventional" chemistry which have either been deliberately omitted from the CHEM Study materials or else are presented from a quite different point of view. Equally important, a number of modern areas with which CHEM Study deals in depth, have been scarcely touched on in the CEEB exams. The CHEM Study, the Examination Committee, and Educational Testing Service are all aware of the problem and are cooperatively seeking a long-term solution to it.

Conclusion

The reader should not be left with the impression that the CHEM Study materials are either a Pandora's box or a panacea. They are tools, the appropriateness and effectiveness of which will depend in large measure on how skillfully they are used. Only the teacher, in his classroom, can determine exactly how a course will be taught, and what adaptations to individual differences can and should be made. In the final analysis, it is the teacher who will be the greatest single determiner of whether a course succeeds or fails.

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12. Newsletter, *Chemical Education Materials Study*, Vol. IV, No. 2, (May, 1964), p. 3.

13. Ibid., p. 4.

14. Ibid., p. 5.

15. Ibid., pp. 6-7.

CHAPTER III

PERSONNEL AND EXPERIMENTAL PROCEDURES

Information concerning the population from which the study sample was drawn, the testing instruments used, and the statistical methods employed to test the hypotheses of the study will be given in this chapter.

Personnel for the Study

The personnel for the study were those students — sophomores, juniors, and seniors — regularly enrolled for first year chemistry courses at North, East, South, and Southeast High Schools, Wichita, Kansas, during the 1962-63 school term.

One first year chemistry class at each of the four high schools was taught using CHEM Study materials, and the other first year chemistry classes were taught using conventional methods. The decision and announcement as to which class at each school would be taught using CHEM Study Materials was not made until after enrollment had been completed, thereby allowing random enrollment in classes.

The distribution of the students included in this study is shown in Table I.

From the total population of 324 conventional and 76 CHEM Study first year chemistry students used in this study, 71 pairs were chosen for the matched pair design. For the investigation of chemistry achievement as it is related to teaching method and grade level, the achievement scored and grade levels for 324 conventional and 76 CHEM Study students were available.

TABLE I

CLASSIFICATION OF STUDENTS INCLUDED IN THE STUDY
BY TYPE OF CHEMISTRY INSTRUCTION AND
HIGH SCHOOL GRADE LEVEL

GRADE	TYPES OF CHEMISTRY Conventional	CHEM Study	TOTAL
Tenth	65	8	73
Eleventh	162	40	202
Twelfth	97	28	125
Totals	324	76	400

Tests Used in the Study

Three tests were used to provide data needed for the study. The Iowa Tests of Educational Development were given to each student in October of his eleventh year. From these data, information was available on each student's achievement level early in his eleventh grade year.

In September, at the beginning of the school term 1962-63, the American Chemical Society Cooperative High School Examination, Form 1961, Part I, was given to all first year chemistry students involved in the study as a pre-experience chemistry test. In May, near the end of the 1962-63 school term, Part II of the ACS Cooperative examination was given as a post-experience chemistry test. The data received were used as the measure of achievement attained by each student in first year chemistry. The following is a description of each test used:

1. Iowa Tests of Educational Development.

The Iowa Tests of Educational Development comprise a test battery yielding nine subtest scores and a composite score. The tests were standardized upon approximately 50,000 students from 290 high schools located in midwestern United States.

Raw scores are converted to standard scores and then to percentile ranks. The test battery is constructed to test what an educated person needs to know and understand about certain important education areas. The results obtained from this test battery give good predictability of college success (1).

2. ACS-NSTA Cooperative Examination, High School, Form 1961.

This examination was prepared by the Examinations Committee of the Division of Chemical Education of the American Chemical Society through its High School Chemistry Subcommittee, appointed jointly by the Examinations Committee and the National Science Teachers Association.

The examination consists of two parts. Each part consists of 50 items and requires 40 minutes. In the manual for this test the author states that it has been constructed so that each part, I or II, covers the entire course. The students may use periodic tables in addition to the test booklet and answer sheet which is provided.

The test was standardized on data from the 1961 National Spring Testing Program (2). These norms are based on the scores of 9173 high school students completing two semesters of chemistry in 142 high schools, as reported by their teachers.

In order to make the norms more meaningful, groups having fairly homogeneous characteristics were isolated. Five sets of norms are given for various grouping.

Random sampling of 3991 papers taken from total returns of 9173 papers gave reliability coefficient, estimated by the Kuder-Richardson Formula No. 21, of 0.934 for Part I, and 0.938 for Part II.

Basis for Matching Pairs

The raw scores made on the quantitative thinking and composite score sections of the Iowa Tests of Educational Development were used as the measure of pre-chemistry mathematical and intellectual development for each member of the 71 matched pairs.

Grade levels were matched identically for the two groups. Raw scores made on the quantitative thinking section were matched identically for the two groups with five exceptions. On pairs 4, 7, 50, and 67 a difference of one raw score was present.[1] On pair 64 a difference of two raw scores was present. The raw scores for the composite score section varied only one point on 22 pairs, two points on 8 pairs, and three points on 4 pairs. A variance greater than three raw score points occurred in only one instance for the 71 matched pairs.

The mean raw score and the standard deviation of the mean raw score for both the quantitative thinking and the composite score sections on the Iowa Tests of Education Development for the groups are

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[1]See Appendix A.

shown in Table II.

TABLE II

MEAN SCORES AND STANDARD DEVIATION OF MEAN SCORES ON THE QUANTITATIVE THINKING AND COMPOSITE SCORE SECTIONS OF THE IOWA TESTS OF EDUCATIONAL DEVELOPMENT FOR THE MATCHED PAIR DESIGN

	CHEM GROUP N = 71		CONVENTIONAL GROUP N = 71	
	$\bar{X}$		$\bar{X}$	
Quantitative Thinking	22.13	0.74	22.07	0.73
Composite Score	22.24	0.59	22.14	0.60

Statistical Methods

Two statistical designs were necessary to test the hypotheses of the study. The hypothesis dealing with a comparison of group achievement in first year chemistry at the high school level was tested by an equivalent group, matched pair design. The analysis of covariance was used to determine the statistical significance of the mean difference found between the two groups in chemistry achievement. One group was composed of 71 students taught first year chemistry from CHEM Study materials and the equivalent group contained the same number of students taught conventional first year chemistry.

The method of statistical analysis used to test the hypothesis concerned with achievement in first year high school chemistry as it is related to method of teaching and grade level was the t-test for significance between means. Grade levels were tenth, eleventh, and twelfth.

Summary

The personnel for the study were those students regularly enrolled for first year chemistry courses at four of the public high schools in Wichita, Kansas, during the school term 1962-63. Each of the four high schools taught one first year chemistry class using CHEM Study materials. All other first year chemistry courses were taught using conventional methos.

Two statistical designs were used for this investigation of chemistry achievement. For the equivalent group, matched pair design using analysis of covariance, 71 students who studied CHEM Study materials were paired with 71 students studying conventional chemistry. For the t-test of significance between means, grade levels and achievement scores were available for 324 conventional and 76 CHEM Study students.

Tests used in the study were as follows: 1) the Iowa Tests of Educational Development, used as the basic instrument for matching the 71 student pairs, and 2) the American Chemical Society Cooperative High School Examination, Form 1961, Part I and Part II, used in first year chemistry to determine prior and post student achievement, respectively.

The analysis of covariance was used to determine the statistical significance of the difference found between the mean raw scores of achievement made by the two sets of 71 matched pairs. The t-test for significance between means was used to test the hypotheses concerned with student achievement in first year chemistry as it is related to grade level, tenth, eleventh, and twelfth.

REFERENCES:

1. Eric F. Gardner, _The Fourth Mental Measurements Yearbook_, ed. Oscar K. Buros, (Highland Park, 1953), p. 45.

2. Norms, _The ACS - NSTA Examination in High School Chemistry, Form 1961_, University of South Florida, Tampa, Florida.

CHAPTER IV

RESULTS OF THE STUDY

The results obtained from comparing the achievement scores for 71 matched pairs of tenth, eleventh, and twelfth grade chemistry students by the analysis of co-variance, and the findings of the t-tests for significance for discovering what relationship exists between student grade level and instructional method in chemistry when compared on the basis of student achievement will be discussed. The statistical data are presented in a series of tables with an interpretation of each table given.

In accordance with the first objective of this study, to determine if student achievement in the CHEM Study course in chemistry is equivalent to student achievement in a conventional course in chemistry, Tables III, IV, V, VI, and Appendix A were prepared.

Tables VII, VIII, and IX present experimental evidence in accordance with the second objective of this study. This evidence is of a nature to discover what relationship exists between student grade level and instructional method in chemistry when compared on the basis of student achievement.

A summary of the results of the study has been included at the end of Chapter IV. This summary, together with all other data furnished, will give a quick overview to those persons interested in the third objective of this study. This objective is to provide information which can be used by teachers, school administrators, parents, and interested citizens in making their own evaluations of the first course in chemistry prepared by CHEM Study.

Equivalent Groups, Matching by Pairs

One hypothesis tested in the study was concerned with the achievement of two equivalent groups of first year chemistry students at the high school level. To test this hypothesis, a statistical comparison of the chemistry achievement of 71 matched pairs of first year chemistry students was made.

All members of one group of 71 students studied first year chemistry from CHEM Study materials while members of the other group received their training in the first course in chemistry in a conventionally oriented class.

The two groups were equated on the basis of their grade level, tenth, eleventh, or twelfth, and their quantitative thinking and composite score results on the Iowa Test of Educational Development.

At the beginning of the school year each student in each group took Part I of the 1961 ACS Examination. At the end of the school year, Part II of the ACS Examination was given to the same students. The mean difference found between the two groups in chemistry achievement was used as the measure of group achievement and the analysis of covariance was used to determine the statistical significance of the mean difference.

The Iowa Tests of Educational Development data used for both the CHEM Study and the conventional groups for pre-chemistry matching of students, are given in Table III. Table III also includes the means for pre-test and post-test achievement scores.

TABLE III

SUMMARY OF DATA FOR MATCHING PAIRS: INCLUDES PRE-TEST, AND POST-TEST MEANS FOR ACHIEVEMENT SCORES

Items in Analysis	Conventional	CHEM Study
Number of Pairs	71	71
Mean, Quantitative Thinking	22.07	22.13
SD, Quantitative Thinking	0.73	0.74
Mean, Composite Score	22.14	22.24
SD, Composite Score	0.60	0.59
t-test Ratio Quantitative Thinking	0.49	
t-test Ratio Composite Score	1.00	
Mean, ACS Examination, Pre-Test	13.78	13.29
Mean, ACS Examination, Post-Test	28.64	29.61

The means and standard deviations of the CHEM Study and the conventional groups vary only slightly for the quantitative thinking and composite score section. This variance in the mean scores between the two groups on the quantitative thinking and composite score section was statistically analyzed by the t-test Ratio (1). The t-test Ratio of 0.49 for the quantitative thinking section and 1.00 for the composite section substantiated the assumption that no significant difference existed between the two groups with respect to these two comparisons.

A preliminary analysis of variance of the pre-test and post-test trials, taken separately, has been made in Table IV.

TABLE IV

ANALYSIS OF VARIANCE OF PRE-TEST AND POST-TEST SCORES TAKEN SEPARATELY

Sources of Variation	d.f.	SS_x	SS_y	$MS_x(V_x)$	$MS_y(V_y)$
Between Means	1	8.64	33.28	8.64	33.28
Within Groups	140	4130.26	13651.09	29.50	97.51
TOTAL	141	4138.90	13684.37	F(pre-test) = 0.29 F(post-test) = 0.34	

S = sum of squares; MS = mean square; V = variance;

x = pre-test; y = post-test

The F test applied to the pre-test achievement scores (F equals .29) falls far short of significance at the .05 level (F equals 3.91) with degrees of freedom 1/140, from which it is clear that the pre-test means do not differ significantly and that the random assignment of subjects to the two groups was quite successful. The F test applied to the post-test, (F equals .34) before correcting for variability in pre-test scores, is also considerably below 3.91, the .05 level.

The analysis of covariance data for correcting the post-test scores for initial differences in pre-test scores is given in Table V.

The F test applied to the post-test achievement scores, (F equals

.79) after the means have been adjusted for any variability in post-test contributed by pre-test, falls far short of the 3.91, the .05 level.

One may conclude, therefore, that when initial differences are allowed for, students taught first year chemistry from CHEM Study materials achieve as well as students taught first year chemistry from a conventional text when students with equal pre-chemistry ability are compared.

TABLE V

ANALYSIS OF COVARIANCE

Sources of Variation	d.f.	SS_x	SS_y	SS_{xy}	$SS_{y.x}$	$MS_{y.x}$ ($V_{y.x}$)	SD $SD_{y.x}$
Between Means	1	8.64	33.28	-16.94	64.09	64.09	
Within Groups	139	4130.26	13651.09	3157.10	11237.86	80.85	8.99
TOTAL	140	4138.90	13684.37	3140.16	11301.95	$F_{y.x}$ = 0.79	

xy = pre-test times post-test; x.y = post-test corrected for pre-test; SD = standard deviation.

The null hypothesis is not rejected and any group differences found in student achievement are the result of chance.

For the difference to have been significant the F test at the .05 level of confidence, with 139 degrees of freedom, would have to have been 3.91.

The coefficient of correlation of .42 for total and within-groups correlation, between the pre-test and post-test achievement scores made by members of the two groups, shows a marked positive relationship in group achievement (2).

The coefficient of correlation of -1.00 for between means of the two groups denotes a very high inverse relationship between achievement on pre-test and post-test achievement scores. That is, members of the conventional group consistently scored lower on the post-test achievement scores than did the latter, but consistently scored higher on the pre-test.

t-Test, Using All Data

The second and third hypotheses to be tested by the study dealt with student achievement in first year chemistry when students were classified under two groups for chemistry instructions, with each of these two groups being further subdivided into three high school grade levels of instructions.

A summary of the classification of students included in this study by type of chemistry instruction and high school grade level was shown in Table I, Chapter III.

In further support of the results of the matched paired design, a t-test for significant difference between means of the two groups was made, using all of the students for which data was collected.

The term "achievement scores" as used here will be taken as the difference between what the student made on his pre-test and post-test ACS Examination scores.

The achievement scores of the 324 students taught first year chemistry by conventional methods were compared with achievement scores of the 76 students studying CHEM Study methods. The achievement means and the variability of the means of the two groups on the ACS Examination, and the value of the t-test comparing the achievement of the two groups are given in Table VI.

The t-test for the achievement scores made by the two groups was .71. This low t-test indicates that for these two groups of chemistry students the difference of 1.70 points between means was not significant.

TABLE VI

SUMMARY OF DATA FOR COMPARING ACHIEVEMENT OF CONVENTIONAL WITH CHEM STUDY GROUP USING t-TEST AND ALL STUDENTS IN THE STUDY

Items in Analysis	Conventional	CHEM Study
Number of Students	324	76
Mean, ACS Examination Scores	16.75	15.05
Standard Deviation	9.29	7.78
Standard Error of the Mean	0.52	0.89
Difference Between Means	1.70	
t-Test	0.71	

The conclusion was drawn from these data that students taught first year chemistry from CHEM Study materials and students taught first year chemistry from a conventional text achieve equally well.

The null hypothesis is not rejected and any group differences found in student achievement are the result of chance.

For the difference to have been significant, the t-test at the .05 level of confidence, with 398 degrees of freedom, would have to have been 1.97.

A check was made to see to what extent variability of group achievement has changed as a result of the two different methods of teaching. The scores used on the ACS Examination were used as the criteria to determine this change in variability.

The difference in the standard deviation for each group was 1.51 points with the conventional group having the greater variance. The standard error of the difference between the two standard deviations was 1.19. The t-test Ratio for these data is 1.27 (3).

With 398 degrees of freedom, the t-test ratio at the .05 level of confidence is 1.97. Because this change in variability is not statistically significant at the .05 level of confidence, one may feel quite confident that students in conventional chemistry do not vary more in general than do students in the CHEM Study group.

Comparisons were made of the scores for the students of each group at each grade level by use of the t-test for significance of difference between means. The mean achievement scores, difference between means and t-test values are shown in Table VII.

The highest degree of freedom found for any comparison in Table VII is 200, the comparison between eleventh grade conventional and eleventh grade CHEM Study.

With 200 degrees of freedom, the t-test for significance at the .05 level of confidence is 1.97. Since none of the calculated t-tests reach the level of 1.97, the conclusion was drawn from these data that students taught first year chemistry from CHEM Study materials achieve as well as students taught first year chemistry from a conventional text regardless of tenth, eleventh, or twelfth grade level.

It is interesting to note that the means of the tenth grade students, both conventional and CHEM Study groups, are higher than the means of the other two grades. This indicates that, on the average, the tenth grade students made the greatest improvement between pre-test and post-test scores.

TABLE VII

COMPARING OF STUDENT ACHIEVEMENT SCORES BY GRADE LEVEL BETWEEN THE CONVENTIONAL AND CHEM STUDY GROUPS

Grade Level and Group	Mean	Difference Between Means	t
Tenth Grade Conventional	20.91	2.41	0.28
Tenth Grade CHEM Study	18.50		
Tenth Grade Conventional	20.91	6.33	1.50
Eleventh Grade CHEM Study	14.58		
Tenth Grade Conventional	20.91	6.16	1.29
Twelfth Grade CHEM Study	14.75		
Eleventh Grade Conventional	15.94	2.56	0.38
Tenth Grade CHEM Study	18.90		

Table VII (continued)

Eleventh Grade Conventional	15.94	1.36	0.43
Eleventh Grade CHEM Study	14.58		
Eleventh Grade Conventional	15.94	1.19	0.32
Twelfth Grade CHEM Study	14.75		
Twelfth Grade Conventional	15.32	3.18	0.48
Tenth Grade CHEM Study	18.50		
Twelfth Grade Conventional	15.32	0.74	0.23
Eleventh Grade CHEM Study	14.58		
Twelfth Grade Conventional	15.32	0.57	0.15
Twelfth Grade CHEM Study	14.75		

An interpretation of this increase, even though the increase is not significant, might suggest one or both of the following: First, only the better students at the tenth grade level may be encouraged to take first year chemistry which by tradition is an eleventh and/or twelfth grade subject. Secondly, the eleventh and twelfth graders because of their additional maturity and experience may tend to score higher on the pre-test than those students at the tenth grade level.

A check was made to see what extent grade level affected achievement within groups taught by the same method. The ACS Examination test scores and the t-test for significance between means were used as the criteria to determine this effect. Tables VIII and IX, conventionally and CHEM Study taught groups respectively, were prepared for this purpose.

The highest degrees of freedom found for any comparison in Table VIII is 257, the comparison between eleventh and twelfth grade levels.

With 257 degrees of freedom, the t-test of significance at the .05 level is 1.97. Since none of the calculated t-tests reach the level of 1.97, the conclusion was drawn that students taught first year chemistry from a conventional text achieve equally as well regardless of grade level.

TABLE VIII

COMPARING OF STUDENT ACHIEVEMENT SCORES BY GRADE LEVEL WITHIN THE CONVENTIONALLY TAUGHT GROUP

Grade Level	Mean	Difference Between Means	t
Tenth Grade	20.91	4.97	1.71
Eleventh Grade	15.94		
Tenth Grade	20.91	5.59	1.73
Twelfth Grade	15.32		
Eleventh Grade	15.94	0.62	0.27
Twelfth Grade	15.32		

While significance at the .05 level was not reached, it is interesting to note that significance was approached by t-test values of

1.71 and 1.73, the comparisons of tenth with eleventh grade and tenth with twelfth grade respectively. Suggested reasons for this difference in means were put forth in the preceding comparison.

In Table IX the comparison between the eleventh and twelfth grade CHEM Study group provided us with the largest degrees of freedom, 66. Entering the t-Table for significance with 66 degrees of freedom gives a value of 2.00 and the .05 level.

Since none of the calculated t's reach the level of 2.00, the conclusion was drawn that students taught first year chemistry from CHEM Study materials achieve equally regardless of grade level, tenth, eleventh, or twelfth.

TABLE IX

COMPARING OF STUDENT ACHIEVEMENT SCORES BY GRADE LEVEL WITHIN THE CHEM STUDY TAUGHT GROUP

Grade Level	Mean	Difference Between Means	t
Tenth Grade	18.50	3.92	0.59
Eleventh Grade	14.58		
Tenth Grade	18.50	3.75	0.52
Twelfth Grade	14.75		
Eleventh Grade	14.58	0.17	0.04
Twelfth Grade	14.75		

It is interesting to note that the calculated t-values for the

CHEM Study group are very low and none of them approach significance. This is in contrast with the within group comparison for the conventionally taught group where two values do approach significance.

Tests of Stated Hypotheses

Three fundamental hypotheses were stated for this study. On the basis of the results obtained from the two statistical analyses used in the study, the null hypotheses are rejected or not rejected at the .05 level of confidence as follows:

Hypothesis 1. There is no significant difference in chemistry achievement between the group of students taught first year high school chemistry from CHEM Study materials and the group of students taught first year high school chemistry from a conventional text when each member of the two groups is a part of a matched pair.

The results found for the equivalent groups, matched pair design, showed that no statistically significant difference existed between the group taught first year high school chemistry from CHEM Study materials and the group of students taught first year high school chemistry from a conventional text.

Therefore, hypothesis number one was not rejected at the .05 level of confidence.

Hypothesis 2. There is no significant difference in chemistry achievement between one group of students taught first year high school chemistry from CHEM Study materials and a group of students taught first year high school chemistry from a conventional text when students are grouped according to grade levels (tenth, eleventh, and twelfth).

The results found, when comparisons were made at each grade level by use of the t-test for significance of difference between means, showed no statistically significant difference, at any one grade level, existed between the group taught first year high school chemistry from CHEM Study materials and the group of students taught first year chemistry from a conventional text.

Therefore, hypothesis number two was not rejected at the .05 level of confidence.

Hypothesis 3. There is no significant difference in chemistry achievement between grade levels (tenth, eleventh, or twelfth) when compared within instructional method, CHEM Study or conventional methods.

The results found when comparisons were made between grade levels within instructional method showed no statistically significant difference existed between grade levels when tested by the t-test for significance of difference between means.

Therefore, hypothesis number three was not rejected at the .05 level of confidence.

Summary

The results of the statistical analysis of the data collected for the study have been presented in Chapter IV. The data were analyzed by the analysis of covariance and the t-test for significance between means.

The analysis of covariance was used to compare differences in chemistry achievement between 71 matched pairs of first year high school chemistry students. Pairs were matched by grade level and the raw scores of the quantitative and composite tests of the Iowa Test of Educational Development. One member of each pair was taught chemistry from CHEM Study materials, while his counterpart received chemistry instruction covering the materials from a conventional text.

No statistically significant difference was found in the chemistry achievement of the two groups.

In further support of the results of the matched-pair design, a t-test for significant difference between means of the two groups using all of the students in the sample, 324 in the conventionally taught group and 76 in the CHEM Study, did not result in any significant difference in achievement between the two groups.

Comparisons were made of the scores for the students of each group at each grade level by use of the t-test for significance of difference between means.

No statistically significant difference was found in the chemistry achievement of the two groups when compared by grade level. However, it is interesting to note that the means of the tenth grade students, both conventional and CHEM Study groups, are higher than the means of the other two grades. This means that, on the average in this sample, the tenth grade students made the greatest improvement between pre-test and post-test scores.

A check was made to see to what extent grade level affected achievement within groups taught by the same method. The achievement scores and the t-test for significance between means were used as the criteria to determine this effect.

No statistically significant difference was found in the chemistry achievement between grade levels within the two groups. However, in the conventional group, significance was approached by t-test values in the comparisons of tenth grade with eleventh and tenth grade with twelfth, with the tenth grade having the greater mean.

REFERENCES:

1. H. E. Garrett, pp. 212-215.
2. Ibid., p. 175.
3. Ibid., p. 232.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The study was designed to present experimental evidence at the high school level which might help to 1) determine if student achievement in the CHEM Study course in chemistry is equivalent to student achievement in a conventional course in chemistry, 2) discover what relationship exists between student grade level and instructional method in chemistry when compared on the basis of student achievement, and 3) provide information which could be used by teachers, school administrators, parents, and interested citizens in making their own evaluations of the CHEM Study method of teaching chemistry.

Null hypotheses were stated that no differences would be found, at the .05 level of confidence, in student achievement in first year high school chemistry between 1) equivalent groups from the type of chemistry studied; 2) groups when grouped according to grade levels, tenth, eleventh, and twelfth; and 3) grade levels when compared within instructional method.

Two different statistical designs were used in an effort to investigate and compare the chemical achievement of CHEM Study and conventional first year high school chemistry students. An equivalent group, matched pair design, was analyzed by the analysis of covariance to test the hypothesis of no difference in chemistry achievement when students were assumed to be of equal chemistry ability at the start of their chemistry instruction. Students were equated on the basis of their grade level and scores on the quantitative thinking and composite score sections of the Iowa Tests of Educational Development.

The t-test was used to test the hypotheses of equal achievement between 1) one group of first year high school chemistry students studying from CHEM Study materials and another group studying a conventional program of first year high school chemistry, when grouped and compared by grade levels, tenth, eleventh, and twelfth; and 2) grade levels, tenth, eleventh, and twelfth, when compared within instructional method.

The raw scores received on the American Chemical Society Examination, High School, Form 1961, were used in all cases as the measure of student achievement in first year high school chemistry. For the t-test analysis the difference between the pre-test and post-test scores of the ACS Examination were used for statistical calculations.

The data collected and the statistical analysis of those data are summarized below under the appropriate statistical design.

1. Equivalent Groups, Matched Pair Design (Analysis of Covariance)

Two types of chemistry instruction were under consideration in the study. These were the CHEM Study first course in chemistry and a conventional program for teaching first year high school chemistry.

The findings of a preliminary analysis of variance of the pre-test achievement scores gave an F variance of .29. An F-value of this magnitude, with the appropriate degrees of freedom, falls far short of significance at the .05 level of confidence, from which it is clear that the pre-test means do not differ significantly and that the random assignment of subjects to the two groups was quite successful.

The analysis of covariance gave an F-value of .79 for the post-test achievement scores. The F-value of .79 falls far short of the 3.91 needed at the .05 level for significance.

Therefore, the null hypothesis was not rejected at the .05 level of confidence, and one may conclude that when initial differences are allowed for, students taught first year chemistry from CHEM Study materials achieve as well as students taught first year chemistry from a conventional text when students with equal pre-chemistry ability are compared.

2. t-Test Analysis

A comparison was made of the achievement scores between the two groups, using all of the students for which data was collected.

The calculated t-test value for these data was .71, which falls short of the .05 level of confidence specified for significance in the design of this study.

Therefore, the null hypothesis is not rejected and offers further support of the results of the analysis of covariance, matched pair design.

Comparisons were made of the scores for the students of each group at each grade level.

The findings of the calculated t-test values for these nine comparisons gave no value statistically significant at the .05 level of confidence.

Therefore, the null hypothesis is not rejected.

Comparisons were made to see to what extent grade level affected achievement within groups taught by the same method.

The findings of the calculated t-test values for the three comparisons made within the conventional group and the three within the CHEM Study group gave no value statistically significant at the .05 level of confidence.

Therefore, the null hypothesis for these two comparisons is not rejected.

Though not a major purpose of this study, a determination was made regarding the effect of each type of chemistry instruction on group variance in chemistry achievement.

The pre-chemistry variance of the two equivalent groups of 71 matched pairs was not significant on the quantitative thinking or composite score sections of the Iowa Tests of Educational Development. The variance of the two groups on the ACS Examination was 1.51 points with the conventional group having the greater variance.

The t-test for these data gives a ratio of 1.27, which is not statistically significant at the .05 level of confidence.

This t-test value reinforces the conclusion drawn from the analysis of covariance.

Conclusions of the Study

The findings of the study appeared to justify the following conclusions:

1. When conventional and CHEM Study first year chemistry groups are equated on the basis of pre-chemistry ability, no significant difference will be found in their chemistry achievement on a conventional chemistry test.

2. When conventional and CHEM Study first year chemistry groups are compared on the basis of grade level, tenth, eleventh, and twelfth, no significant difference will be found in their chemistry achievement on a conventional chemistry test.

3. When grade levels within the conventionally taught group are compared on a conventional chemistry test, no significant difference will be found in their chemistry achievement. However, tenth graders appear to make the greatest improvement, and this improvement approaches significance.

4. When grade levels within the CHEM Study taught group are compared on a conventional chemistry test, no significant difference will be found in their chemistry achievement.

5. Over all, tenth grade students, both conventional and CHEM Study groups, appear to make greater improvements than the other two grades when compared on a conventional chemistry test.

6. Compared on the basis of student achievement on a conventional chemistry test, CHEM Study students appear to achieve as well as students in a conventional course, regardless of grade level. Also, students within groups appear to achieve as well regardless of grade level.

Recommendations

The writer makes the following recommendations as the result of this study:

1. Additional research can and should be done to further explore the areas considered in this study.

2. More useful information would likely come from a number of

studies, performed under a variety of conditions.

3. The effect a CHEM Study program has upon achievement in other science courses needs investigating.

4. Research is needed on the motivational effect and holding power of the CHEM Study program upon secondary school students.

5. The evidence from current data is sufficient to inform administrators that achievement in a CHEM Study program is equal to achievement in the conventional approach.

6. Research is needed on the college success of students who have studied from the CHEM Study program in secondary school.

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APPENDIX A

GRADE LEVELS AND THE RAW SCORES ON THE QUANTITATIVE THINKING AND COMPOSITE SCORE SECTIONS OF THE IOWA TESTS OF EDUCATIONAL DEVELOPMENT AND THE ACS HIGH SCHOOL CHEMISTRY EXAMINATION FOR 71 MATCHED PAIRS

		Quantitative Thinking		Composite Score		ACS Examination			
						CHEM		Conv.	
Pair Number	Grade Level	CHEM	Conv.	CHEM	Conv.	Pre	Post	Pre	Post
1	10	29	29	33	32	21	39	18	43
2	10	29	29	23	27	20	40	20	35
3	10	27	27	26	26	19	33	14	46
4	10	11	12	17	16	13	31	27	10
5	10	11	31	28	27	18	26	18	29
6	10	33	33	32	34	26	47	14	52
7	10	32	31	25	25	7	39	12	39
8	10	27	27	28	29	19	36	19	30
9	11	19	19	18	18	11	19	11	33
10	11	27	27	24	23	11	23	14	36
11	11	27	27	25	25	12	30	16	41
12	11	25	25	24	25	37	31	13	40
13	11	31	31	26	25	8	45	12	27
14	11	21	21	23	23	11	20	20	31
15	11	18	18	19	19	11	24	9	30
16	11	35	35	35	33	18	43	15	47
17	11	24	24	22	24	16	23	8	31
18	11	14	14	19	18	12	21	12	14
19	11	18	18	19	18	25	38	10	20
20	11	12	12	11	12	18	15	10	25
21	11	18	18	19	18	18	31	15	16
22	11	16	16	18	18	11	26	12	25
23	11	20	20	16	16	12	24	4	15
24	11	21	21	20	20	14	19	9	30
25	11	19	19	21	21	10	15	9	18
26	11	15	15	15	15	11	16	10	30
27	11	10	10	15	12	1	23	3	30
28	11	25	25	21	21	18	32	20	43
29	11	14	14	19	19	8	18	6	18
30	11	22	22	21	21	14	27	15	26
31	11	18	18	11	12	13	13	13	16
32	11	15	15	19	18	20	39	14	14
33	11	23	23	23	23	10	40	13	30
34	11	21	21	21	21	13	25	13	31

APPENDIX A (Continued)

35	11	21	21	25	24	21	45	11	26
36	11	24	24	22	21	10	26	6	32
37	11	15	15	16	17	9	26	12	24
38	11	28	28	25	25	13	34	14	21
39	11	26	26	25	23	14	37	18	44
40	11	28	28	25	25	24	42	15	43
41	11	33	33	27	30	15	33	13	36
42	11	25	25	21	22	11	30	12	27
43	11	13	13	26	21	10	29	11	30
44	11	21	21	20	20	15	30	12	16
45	11	18	18	20	18	10	23	5	28
46	11	26	26	23	23	11	36	12	20
47	12	16	16	19	18	10	22	10	22
48	12	23	23	24	22	15	30	14	40
49	12	19	19	19	19	12	34	16	11
50	12	11	10	15	14	9	31	12	29
51	12	25	25	26	27	12	38	18	43
52	12	15	15	21	23	15	25	15	32
53	12	19	19	22	22	10	14	11	37
54	12	15	15	17	17	5	11	11	34
55	12	24	24	21	24	16	23	8	24
56	12	20	20	21	21	3	14	17	24
57	12	12	12	15	16	7	16	11	29
58	12	21	21	20	19	10	23	12	26
59	12	21	21	22	23	20	27	13	18
60	12	20	20	17	17	6	18	14	25
61	12	19	19	23	21	10	30	10	10
62	12	24	24	23	23	7	37	14	20
63	12	23	23	24	24	13	37	14	27
64	12	33	31	30	30	17	42	21	43
65	12	21	21	24	24	13	39	11	22
66	12	28	28	29	26	13	29	13	56
67	12	35	34	36	36	20	37	41	59
68	12	24	24	22	24	14	17	10	21
69	12	29	29	23	24	15	23	13	34
70	12	29	29	30	30	18	31	16	38
71	12	20	20	25	25	15	27	13	40

A.C.S. - N.S.T.A. COOPERATIVE EXAMINATION

HIGH SCHOOL CHEMISTRY

FORM 1961 SERIAL NO. 82494

pared by the Examinations Committee of the Division of Chemical Education of the American Chemical Society through its High School Chemistry Subcommittee, appointed jointly by the Examinations Committee and the National Science Teachers Association

TO THE EXAMINER: For full instructions refer to DIRECTIONS FOR ADMINISTRATION, except that the students may use periodic tables for this test. This test has been constructed so that each part, I or II, covers the entire course. Each part is equally valid. If both parts are taken a more thorough sampling is attained, thus increasing the reliability. Each part consists of 50 items and requires 40 minutes or a total of 100 items requiring 80 minutes.

The teacher has the choice of using either part or both parts. The entire test may be given in two 40-45 minute periods, or in a single 80-90 minute period. Separate norms will be provided for either part and for the total.

All student responses are to be recorded on a special answer sheet, not written in the booklet. Each student should be provided with a sheet of scratch paper which should be submitted with the answer sheet at the close of the examination period.

TO THE STUDENT: DO NOT WRITE ANYTHING IN THIS BOOKLET. Do not turn this page until your instructor gives the signal. When he tells you to begin, open the booklet, read the directions, and begin answering the questions. When you have decided which one answer to each question is correct, blacken the corresponding space on the answer sheet with your pencil. Make a heavy full black mark, but no stray marks.

You may answer questions even when you are not perfectly sure that your answers are correct, but you should avoid wild guessing, since wrong answers will result in a subtraction from the number of correct answers. There is only **one** correct answer to each question. DO NOT SPEND TOO MUCH TIME ON ANY ONE QUESTION. Answer the easier ones first and then return to the harder ones if time permits.

Part	Items	Minutes
I	50	40
II	50	40
Total	100	80

DIRECTIONS: Each item consists of a stem to which one response is correct among the several numbered choices given. For each item, blacken the space on your answer sheet that has the same number as that of the response you have selected as the correct answer.

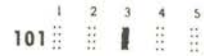
Whenever possible, arrive at your own answer to a question before looking at the response. Otherwise you may be misled by plausible incorrect responses.

Sample Question:

101. Of what is water composed? (Stem)

- (1) Hydrogen and nitrogen
- (2) Carbon monoxide and hydrogen
- (3) Hydrogen and oxygen
- (4) Sulfur and phosphorus (Responses)
- (5) Nitrogen and oxygen

Sample Answer Sheet:



(The correct answer is response (3), "Hydrogen and oxygen". Answer space 3 therefore has been marked on the sample answer sheet.)

PART I

(40 minutes)

1. Which process yields the most nearly chemically pure water?
   - (1) Filtration
   - (2) Coagulation
   - (3) Electrolysis
   - (4) Sedimentation
   - (5) Distillation

2. Since sodium and potassium are both members of Group IA in the Periodic Table, a sodium and a potassium atom have the same
   - (1) atomic weight.
   - (2) number of protons in their nuclei.
   - (3) atomic number and the same nuclear charge.
   - (4) characteristic of losing one electron per atom to form an ion.
   - (5) total number of electrons around the nucleus.

3. The chemical properties of atoms depend principally upon
   - (1) their atomic weight.
   - (2) the masses of the nuclei involved.
   - (3) the number of neutrons in their nuclei.
   - (4) the ratio in which the atoms combine with other atoms.
   - (5) the number of electrons in their outermost shells.

4. The type of bond formed when two atoms share a pair of electrons is called
   - (1) ionic.
   - (2) double.
   - (3) covalent.
   - (4) bivalent.
   - (5) electrovalent.

5. Which statement best accounts for the fact that gases can be greatly compressed?
   - (1) Molecules occupy space.
   - (2) The collisions of molecules are elastic.
   - (3) Molecules of gases are in constant motion.
   - (4) The molecules of a given gas are identical.
   - (5) Molecules of gases are relatively far from each other.

6. Which metallic ion is most responsible for "hardness" in water?
   - (1) K^+
   - (2) Li^+
   - (3) Na^+
   - (4) Zn^{++}
   - (5) Ca^{++}

7. Two kinds of emission from radioactive substances that are considered to be particles of matter are
   - (1) alpha and beta emission.
   - (2) alpha and gamma emission.
   - (3) beta and gamma emission
   - (4) gamma emission and x-radiation.
   - (5) alpha emission and x-radiation.

8. The total number of atoms represented by the formula $K_3Fe(CN)_6$ is
   - (1) 4
   - (2) 10
   - (3) 11
   - (4) 16
   - (5) 36

Go on to the next page.

9. The reaction between sodium chloride and concentrated sulfuric acid produces

   (1) chlorine.
   (2) hydrogen chloride.
   (3) sulfur dioxide.
   (4) sulfur trioxide.
   (5) sodium sulfide.

0. The mass number of an atom of iodine is 127, and the atomic number is 53. The number of protons in the nucleus of this iodine atom is

   (1) 7
   (2) 53
   (3) 74
   (4) 127
   (5) 180

1. Which ions account for the alkalinity of bases in water solution?

   (1) Oxide ions
   (2) Hydronium (hydrogen) ions
   (3) Sodium ions
   (4) Ammonium ions
   (5) Hydroxide (hydroxyl) ions

2. The similar chemical behavior of the elements in a given family in the Periodic Table is best accounted for by the fact that atoms of these elements have

   (1) the same number of electrons in the outermost shell.
   (2) the same number of electrons.
   (3) the same number of protons.
   (4) similar nuclear structures.
   (5) a common origin.

3. Which equation is correctly written?

   (1) $Ca + H_2O \rightarrow CaO + H_2$
   (2) $Ca + H_2O \rightarrow CaOH + H$
   (3) $Ca + 2\ H_2O \rightarrow Ca(OH)_2 + H_2$
   (4) $Ca + 2\ H_2O \rightarrow Ca(OH)_2 + 2\ H$
   (5) $2\ Ca + 6\ H_2O \rightarrow 2\ Ca(OH)_3 + 3\ H_2$

4. All positive ions differ from their corresponding atoms by having

   (1) larger diameters.
   (2) fewer electrons.
   (3) a charge of +1.
   (4) greater atomic weights.
   (5) stronger metallic properties.

5. Which is a characteristic property of hydrogen?

   (1) It diffuses slowly.
   (2) It is denser than helium.
   (3) It burns readily in air.
   (4) It is very soluble in water.
   (5) It reacts readily with copper.

16. Which pH value signifies the highest hydronium (hydrogen) ion concentration?

   (1) pH 5
   (2) pH 7
   (3) pH 9
   (4) pH 11
   (5) pH 14

17. Which symbol represents an atom that contains the largest number of neutrons?

   (1) ${}_{92}U^{235}$
   (2) ${}_{92}U^{239}$
   (3) ${}_{93}Np^{239}$
   (4) ${}_{94}Pu^{239}$
   (5) ${}_{91}Pa^{231}$

18. Large quantities of oxygen for commercial use are prepared by

   (1) heating mercuric oxide.
   (2) heating potassium chlorate.
   (3) the fractional distillation of liquid air.
   (4) heating limestone to produce calcium carbide and oxygen.
   (5) the action of chlorine on water producing hydrochloric acid and oxygen.

19. Under the same conditions of temperature and pressure, a liter of hydrogen compared to a liter of oxygen contains

   (1) more molecules than the liter of oxygen.
   (2) fewer molecules than the liter of oxygen.
   (3) the same number of molecules as the liter of oxygen.
   (4) molecules with lower average velocity than the oxygen molecules.
   (5) the same total weight of gas as the liter of oxygen.

20. In the reaction, represented by the equation, $Mg + CuSO_4 \rightarrow MgSO_4 + Cu$,

   (1) copper is oxidized.
   (2) magnesium is reduced.
   (3) magnesium is the reducing agent.
   (4) the sulfate ion is the oxidizing agent.
   (5) the oxidation number of the copper remains unchanged.

21. Isomers have

   (1) different atomic weights but the same atomic numbers.
   (2) the same molecular structure and molecular weights.
   (3) the same atomic number but different atomic weights.
   (4) different molecular weights but the same molecular structures.
   (5) different molecular structures but the same number and kind of atoms.

Go on to the next page.

22. A chemical reaction in water solution in which two or more products are formed will go nearly to completion when

(1) two salts are mixed.
(2) the reactants are soluble.
(3) ionization of the products occurs.
(4) the proportions of the reactants are equal.
(5) one of the products escapes as a gas.

23. Which of these metals combines most readily with oxygen?

(1) Zinc
(2) Iron
(3) Copper
(4) Sodium
(5) Aluminum

24. The gas usually formed by the chemical combination of nitrogen and hydrogen reacts with water to form

(1) HNO_3
(2) NH_3
(3) NO_2^-
(4) NO_3^-
(5) NH_4^+

25. At the anode in an electroplating cell, the chemical action is called

(1) oxidation.
(2) hydrolysis.
(3) dissociation.
(4) reduction.
(5) neutralization.

26. Which equation most nearly represents the reaction between hydrogen chloride and water?

(1) $HCl + H_2O \rightarrow 3\ H^+ + ClO^-$
(2) $HCl + H_2O \rightarrow H_3O^+ + Cl^-$
(3) $HCl + H_2O \rightarrow 2\ H^+ + OH^- + O^{--} + Cl^-$
(4) $HCl + H_2O \rightarrow 3\ H^+ + Cl^- + O^{--}$
(5) $HCl + H_2O \rightarrow H_3^+ + ClO^-$

27. The combination of hydronium ions with hydroxide ions is known as

(1) catalysis.
(2) hydrolysis.
(3) electrolysis.
(4) hydrogenation.
(5) neutralization.

28. Which volume is most nearly equivalent to 3 quarts?

(1) 0.3 liter
(2) 3 deciliters
(3) 0.3 kiloliter
(4) 3000 milliliters
(5) 300 cubic centimeters

29. One liter of oxygen at STP contains approximately the same number of molecules as

(1) 2 liters of He at STP.
(2) 1/3 liter of O_3 at STP.
(3) 1 liter of CO_2 at STP.
(4) 1/5 liter of CH_4 at STP.
(5) 250 milliliters of NH_3 at STP.

30. Covalent bonds are most likely to be found in the compound represented by the formula

(1) NaCl
(2) KBr
(3) CH_4
(4) KI
(5) CaF_2

31. The outermost shell of element "X" has 3 electrons while that of element "Y" has 6. The probable formula of a compound of these elements is

(1) X_3Y_2
(2) X_2Y_3
(3) XY
(4) X_2Y
(5) XY_2

32. The best explanation of the extreme activity of fluorine as compared to other halogens is that the fluorine atom

(1) has the smallest atomic radius.
(2) has the smallest nuclear charge.
(3) has seven valence electrons.
(4) is the strongest reducing agent.
(5) needs one electron to complete its outermost shell.

33. A colloidal dispersion forms when $FeCl_3$ hydrolyzes in hot water. The dispersion

(1) settles out after standing a few hours.
(2) turns blue on exposure to light.
(3) scatters light rays.
(4) is easily oxidized on exposure to air.
(5) is easily separated by filtration.

34. Which salt gives a water solution having a basic reaction to litmus?

(1) Potassium chloride
(2) Sodium acetate
(3) Sodium chloride
(4) Silver nitrate
(5) Aluminum sulfate

35. At which temperature will water, in an open vessel, dissolve the greatest quantity of oxygen

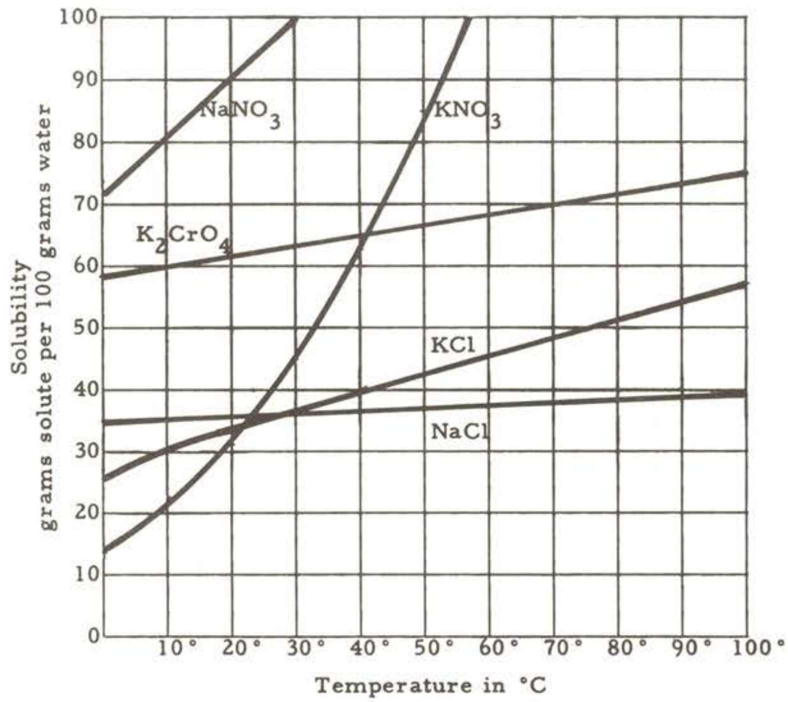
(1) 1 °C
(2) 4 °C
(3) 20 °C
(4) 32 °C
(5) 100 °C

Go on to the next page.

6. The chlorine atom and the chloride ion have the same
   (1) nuclear charge.
   (2) number of electrons.
   (3) chemical properties.
   (4) physical properties.
   (5) oxidizing ability.

37. In the reaction, represented by the equation, H_2F_2 + Energy ⇌ 2 HF, which set of conditions favors the formation of HF?
   (1) Low temperature and high pressure
   (2) Low temperature and low pressure
   (3) High temperature and high pressure
   (4) High temperature and low pressure
   (5) Addition of water to the reaction mixture

USE THIS GRAPH IN ANSWERING QUESTIONS 38, 39, AND 40.



38. Which of these solutes is least soluble in water at 10°C?
   (1) KCl
   (2) KNO_3
   (3) NaCl
   (4) $NaNO_3$
   (5) K_2CrO_4

39. Which solution contains the greatest weight of solute in 100 grams of water?
   (1) A saturated solution of NaCl at 100°C
   (2) A saturated solution of KCl at 50°C
   (3) A saturated solution of $NaNO_3$ at 25°C
   (4) A saturated solution of KNO_3 at 25°C
   (5) A saturated solution of K_2CrO_4 at 50°C

40. What is the least amount of water needed to dissolve 50 grams of KNO_3 at 30°C?
   (1) 30 grams
   (2) 45 grams
   (3) 50 grams
   (4) 90 grams
   (5) 111 grams

Go on to the next page.

USE THESE ATOMIC WEIGHTS IN ANSWERING SOME OF THE QUESTIONS IN THIS SECTION OF THE TEST:

Symbol	Atomic Weight	Symbol	Atomic Weight	Symbol	Atomic Weight
Al	27.0	H	1.0	Na	23.0
C	12.0	K	39.0	O	16.0
Ca	40.0	Mg	24.0	P	31.0
Cl	35.5	Mn	55.0	S	32.0
F	19.0	N	14.0	W	184.0

41. A sample of air has a volume of 150 milliliters. The pressure on the air is doubled and its original temperature is restored. The new volume is approximately

(1) 75 milliliters.
(2) 300 milliliters.
(3) 450 milliliters.
(4) 600 milliliters.
(5) 750 milliliters.

42. Twenty-five milliliters of an acid neutralize 50 milliliters of a 2.0 base. The normality of the acid is

(1) 1.0 N
(2) 2.0 N
(3) 3.0 N
(4) 4.0 N
(5) 5.0 N

43. How many milliliters of oxygen combine completely with 32 milliliters of hydrogen to form water? (Assume that both gases are at STP.)

(1) 16 milliliters
(2) 22.4 milliliters
(3) 32 milliliters
(4) 64 milliliters
(5) 96 milliliters

44. Given the following equation: $N_2 + 3\ H_2 \rightarrow 2\ NH_3$ Theoretically, the number of moles of ammonia produced from 2 moles of nitrogen is

(1) 1
(2) 2
(3) 3
(4) 4
(5) 5

45 If the density of a certain gas at 273° Kelvin (absolute) and 760 millimeters of mercury pressure is 1.40 grams per liter, its molar weight may be found by the expression

(1) $1.40 \times 4 \times 22.4$
(2) 1.40×22.4
(3) $1.40 \times 2 \times 22.4$
(4) $\frac{2 \times 22.4}{1.40}$
(5) $\frac{760 \times 1.40 \times 22.4}{273}$

46. The number of moles of water in 1,000 grams of water is

(1) 18.0
(2) 55.5
(3) 180.0
(4) 1000.0
(5) 18,000.0

47. The weight of a liter of fluorine (F_2) at STP is most nearly

(1) $\frac{19}{22.4}$ grams
(2) $\frac{22.4}{19}$ grams.
(3) $\frac{2 \times 22.4}{19}$ grams.
(4) $\frac{38}{22.4}$ grams.
(5) $\frac{22.4}{38}$ grams.

48. In an experiment, 5.6 liters of chlorine at STP was released according to this equation:

$$4\ HCl + MnO_2 \rightarrow MnCl_2 + 2\ H_2O + Cl_2$$

The weight of manganous chloride produced at the same time is most nearly

(1) 12 grams.
(2) 24 grams.
(3) 32 grams.
(4) 42 grams.
(5) 84 grams.

49. A compound is composed of 92.32% carbon and 7.68% hydrogen, by weight. At STP, 11.2 liters of its vapor weighs 39 grams. What is its molecular formula?

(1) CH
(2) C_3H_3
(3) C_2H_2
(4) C_4H_{18}
(5) C_6H_6

50. Under similar conditions, which of these gases diffuses most rapidly through a small opening?

(1) CH_4
(2) CO_2
(3) SO_2
(4) O_2
(5) Cl_2

End of Part I.

CONTINUE TO PART II, UNLESS OTHERWISE INSTRUCTED.

PART II

A.C.S. - N.S.T.A.
COOPERATIVE EXAMINATION
IN

HIGH SCHOOL CHEMISTRY

FORM 1961

START IMMEDIATELY ON PART II UNLESS OTHERWISE INSTRUCTED

DIRECTIONS: Each item consists of a stem to which one response is correct among the several numbered choices given. For each item, blacken the space on your answer sheet that has the same number as that of the response you have selected as the correct answer.

Whenever possible, arrive at your own answer to a question before looking at the response. Otherwise you may be misled by plausible incorrect responses.

Sample Question:

101. Of what is water composed? (Stem)

(Responses)
- (1) Hydrogen and nitrogen
- (2) Carbon monoxide and hydrogen
- (3) Hydrogen and oxygen
- (4) Sulfur and phosphorus
- (5) Nitrogen and oxygen

Sample Answer Sheet:

101 (1) (2) ▌(3) (4) (5)

(The correct answer is response (3), "Hydrogen and oxygen". Answer space 3 therefore has been marked on the sample answer sheet.)

PART II

(40 minutes)

51. The number of electrons in an atom of any free element is equal to
    - (1) the number of protons in the nucleus.
    - (2) the number of neutrons in the nucleus.
    - (3) the sum of the number of neutrons and protons.
    - (4) the atomic weight less the number of protons.
    - (5) the atomic number less the number of neutrons.

52. In the modern Periodic Table the elements are arranged in the order of increasing
    - (1) atomic weights.
    - (2) atomic radii.
    - (3) atomic volumes.
    - (4) atomic numbers.
    - (5) atomic masses.

53. The kind of molecules found in gasoline are mainly
    - (1) carbohydrates.
    - (2) hydrocarbons.
    - (3) esters.
    - (4) ketones.
    - (5) alcohols.

54. Aluminum hydroxide is an amphoteric compound. This means that aluminum hydroxide
    - (1) is highly colored.
    - (2) is used as a reducing agent.
    - (3) is insoluble in strong bases.
    - (4) is insoluble in strong acids.
    - (5) can act either as a weak acid or a weak base.

55. Enough acid is added to a solution having pH 13 to change the pH to 7. This is an example of
    - (1) catalysis.
    - (2) hydrolysis.
    - (3) electrolysis.
    - (4) neutralization.
    - (5) hydrogenation.

56. Four of these processes normally consume oxygen. Which one does <u>not</u>?
    - (1) Combustion
    - (2) Rusting of iron
    - (3) Respiration in animals
    - (4) Photosynthesis in plants
    - (5) The operation of an acetylene torch

57. As far as can be detected by analytical balances, in any chemical reaction, the sum of the weights of all the reactants
    - (1) always equals the sum of the weights of all the products.
    - (2) is less than that of the products if a precipitate is formed.
    - (3) is greater than that of the products if a gas is formed.
    - (4) usually equals that of the products.
    - (5) never equals that of the products.

58. The difference between the atomic number of an atom and its mass number gives the number of
    - (1) protons.
    - (2) neutrons.
    - (3) energy levels.
    - (4) orbitals.
    - (5) electrons.

Go on to the next page.

). "M" represents a metallic element, the oxide of which has the formula M_2O. The formula of the chloride of M is

(1) MCl

(2) MCl_2

(3) MCl_3

(4) MCl_4

(5) M_2Cl

). The formula of potassium tungstate is K_2WO_4. The oxidation number (valence) of W (tungsten) in this compound is

(1) -2

(2) +2

(3) +4

(4) +6

(5) +8

l. When sulfur dioxide is converted into sulfur trioxide, each sulfur atom

(1) is reduced.
(2) gains one electron.
(3) gains five electrons.
(4) loses three electrons.
(5) has its oxidation number changed.

?. An atom of a metal becomes an ion by

(1) the loss of one or more electrons.

(2) the gain of one or more protons.

(3) the gain of one or more electrons.

(4) the loss of one or more protons.

(5) the gain of one or more neutrons.

}. Which of these compounds is least soluble in water?

(1) Potassium chloride
(2) Silver chloride
(3) Magnesium chloride
(4) Calcium chloride
(5) Sodium nitrate

:. Oxidation always involves

(1) oxygen.
(2) burning.
(3) transfer of protons.
(4) transfer of electrons.
(5) the formation of oxides.

65. Which is the formula of the most likely by-product from a common laboratory method of preparing hydrogen from an acid?

(1) $ZnCO_3$
(2) NaCl
(3) $ZnSO_4$
(4) $HgCl_2$
(5) ZnS

66. The atoms of the isotopes of hydrogen

(1) have one proton but differ in the number of electrons.

(2) have one proton but differ in the number of neutrons.

(3) have the same mass.

(4) differ in the number of protons.

(5) differ in the number of valence electrons.

67. The formula of an oxide which reacts with water to form an acid is

(1) CaO

(2) ZnO

(3) P_4O_{10}

(4) Al_2O_3

(5) Li_2O

68. When one exhales through limewater, the precipitate formed is

(1) CaO

(2) $Ca(NO_3)_2$

(3) $Ca(OH)_2$

(4) $CaCO_3$

(5) $CaSO_4$

69. In general, the solubility of gases in water

(1) decreases as pressure increases.

(2) is not affected by pressure change.

(3) is constant for all types of gases.

(4) is not affected by temperature changes.

(5) decreases as temperature increases.

70. Which equation represents the complete combustion of acetylene in an excess of air?

(1) $C_2H_2 + 2\ O_2 \rightarrow 2\ CO_2 + H_2$

(2) $C_2H_2 + O_2 \rightarrow 2\ CO + H_2$

(3) $C_2H_2 + O \rightarrow 2\ C + H_2O$

(4) $C_2H_2 + O_2 \rightarrow 2\ C + H_2O_2$

(5) $2\ C_2H_2 + 5\ O_2 \rightarrow 4\ CO_2 + 2\ H_2O$

Go on to the next page.

71. Which electron configuration is most characteristic of an active nonmetallic element?

(1) 2)8)1

(2) 2)8)3

(3) 2)8)5

(4) 2)8)7

(5) 2)8)8

72. Liquids which appear homogeneous to the eye but are not homogeneous when viewed under the ultra-microscope are called

(1) true solutions.
(2) pure substances.
(3) coarse suspensions.
(4) saturated solutions.
(5) colloidal dispersions.

73. Which is a measure of the degree of stability of a particular radioactive nucleus?

(1) Density
(2) Half life
(3) Atomic weight
(4) Atomic number
(5) Ionization potential

74. A metal, which is not Zn, is placed in a solution of $ZnCl_2$ with no apparent effect. In $Pb(NO_3)_2$ solution, the metal appears to be coated with some material. This evidence suggests that the metal is

(1) more active than Zn and Pb.

(2) less active than Zn and Pb.

(3) more active than Pb but less active than Zn.

(4) more active than Zn but less active than Pb.

(5) as active as Pb.

75. The electrolysis of melted sodium chloride yields

(1) sodium hydroxide, hydrogen and chlorine.

(2) sodium hydroxide and hydrogen chloride.

(3) sodium hydroxide, oxygen, and hydrogen.

(4) sodium and chlorine.

(5) sodium hydroxide and water.

76. The hydronium (hydrogen) ion is a complex ion composed of water and

(1) an electron.
(2) a deuteron.
(3) a proton.
(4) a neutron.
(5) a positron.

77. Which formula represents methyl chloride?

(1) CH_3Cl

(2) C_2H_5Cl

(3) C_3H_7Cl

(4) C_4H_9Cl

(5) $C_5H_{11}Cl$

78. In the Periodic Table, the metallic character of the elements generally increases reading from

(1) left to right.
(2) bottom to top.
(3) left to right and bottom to top.
(4) left to right and top to bottom.
(5) right to left and top to bottom.

79. The temperature at which water boils is

(1) the temperature at which the vapor pressure is always 760 millimeters of mercury.

(2) the temperature at which the vapor pressure is equal to the atmospheric pressure.

(3) the temperature at which the vapor pressure is zero.

(4) independent of pressure.

(5) the critical temperature of water.

80. In the reaction, $N_2 + 3H_2 \rightleftharpoons 2NH_3$, an increase in pressure forces the reaction to the right because

(1) hydrogen diffuses more rapidly than nitrogen.

(2) there are fewer molecules in the product than in the reactants.

(3) ammonia is a gas.

(4) ammonia is very soluble in water.

(5) the product weighs more than either reactant.

81. Nitric acid can be used as

(1) a hydrating agent.
(2) a reducing agent.
(3) an oxidizing agent.
(4) a precipitating agent.
(5) a dehydrating agent.

82. A new silver coin placed in a beaker of hydrochloric acid

(1) liberates chlorine.

(2) liberates hydrogen.

(3) liberates both hydrogen and chlorine.

(4) precipitates silver chloride.

(5) produces no observable reaction.

Go on to the next page.

. Which expression represents the oxidation of the cuprous ion?

(1) $Cu^+ - e^- \rightarrow Cu^{++}$

(2) $Cu^+ + e^- \rightarrow Cu^o$

(3) $Cu^+ + e^- \rightarrow Cu^{++}$

(4) $Cu^o - e^- \rightarrow Cu^+$

(5) $Cu^{++} + e^- \rightarrow Cu^+$

. If the radioactive atom, ${}_{92}U^{238}$, emits an alpha particle, the atom remaining is represented by

(1) ${}_{92}U^{238}$

(2) ${}_{92}Th^{236}$

(3) ${}_{92}U^{234}$

(4) ${}_{90}Th^{234}$

(5) ${}_{91}Pa^{234}$

. The compounds H_2S, H_2Se, and H_2Te boil below 0 °C at standard pressure. Water (H_2O) boils at 100 °C. This abnormally high boiling point of water is a consequence of the

(1) low molecular weight of water.

(2) low electrical conductivity of water.

(3) covalent bonds in the water molecule.

(4) stability of the bonds in the water molecules.

(5) hydrogen bonds between the water molecules.

. Five different solutions were prepared by dissolving 0.1 gram formula weight of each of these materials in one liter of water. Which solution has the lowest freezing point?

(1) K_2SO_4

(2) H_2SO_4

(3) Na_3PO_4

(4) HCl

(5) NaOH

87. For which of these is the equivalent weight equal to the gram formula weight?

(1) $CaCl_2$

(2) K_2SO_4

(3) Ag_2CrO_4

(4) H_3PO_4

(5) NH_4Br

Answer questions 88, 89 and 90 using the following information:

To 24.5 grams of pure H_2SO_4 enough water is added to prepare 750 ml of solution. Formula weight of H_2SO_4 is 98.

88. The number of moles of H_2SO_4 used is

(1) 0.25
(2) 0.33
(3) 0.50
(4) 0.66
(5) 1.00

89. The molarity of the solution is approximately

(1) 0.25
(2) 0.33
(3) 0.66
(4) 1.00
(5) 1.33

90. The normality of the solution is approximately

(1) 0.25
(2) 0.33
(3) 0.66
(4) 1.00
(5) 1.33

Go on to the next page.

USE THESE ATOMIC WEIGHTS IN ANSWERING SOME OF THE QUESTIONS IN THIS SECTION OF THE TEST:

Symbol	Atomic Weight	Symbol	Atomic Weight	Symbol	Atomic Weight
Al	27.0	H	1.0	Na	23.0
C	12.0	K	39.0	O	16.0
Ca	40.0	Mg	24.0	P	31.0
Cl	35.5	Mn	55.0	S	32.0
F	19.0	N	14.0	W	184.0

91. A dry gas has a volume of 200 ml at 25°C and 740 millimeters of mercury pressure. Which expression gives the volume of the gas in milliliters at STP?

(1) $200 \times \frac{273}{298} \times \frac{760}{740}$

(2) $200 \times \frac{0}{25} \times \frac{760}{740}$

(3) $\frac{200}{22.4} \times \frac{298}{273} \times \frac{1000}{740}$

(4) $200 \times \frac{273}{298} \times \frac{740}{760}$

(5) $200 \times \frac{298}{273} \times \frac{740}{1}$

92. How many milliliters of 0.25 N NaOH is required to neutralize 40 ml of 0.10 N HCl?

(1) 16
(2) 25
(3) 40
(4) 50
(5) 100

93. How many grams of calcium nitrate, [$Ca(NO_3)_2$, formula weight 164] must be dissolved in water to make 500 milliliters of a one-molar solution?

(1) 82
(2) 102
(3) 150
(4) 164
(5) 328

94. A sample of sulfur dioxide gas weighs 16 grams. The weight of the same number of molecules of nitrogen gas is

(1) 7 grams.
(2) 14 grams.
(3) 16 grams.
(4) 28 grams.
(5) 56 grams.

95. What is the equivalent weight of aluminum? (Atomic weight 27, valence 3, specific gravity 2.7)

(1) 0.9
(2) 8.1
(3) 9.0
(4) 27.0
(5) 81.0

96. The percent of water of crystallization in $MgSO_4 \cdot 7\,H_2O$ is

(1) 4.8%
(2) 6.6%
(3) 25.6%
(4) 48.8%
(5) 51.2%

97. What is the volume of carbon dioxide, measured at STP, formed by the complete combustion of 15 grams of ethane gas according to this equation:

$$2\,C_2H_6 + 7\,O_2 \rightarrow 4\,CO_2 + 6\,H_2O$$

(1) 5.6 liters
(2) 11.2 liters
(3) 22.4 liters
(4) 44.8 liters
(5) 89.6 liters

98. A compound is composed of 80% C and 20% H. What is its simplest formula?

(1) CH
(2) CH_2
(3) CH_3
(4) C_2H_6
(5) C_4H

99. What is the maximum weight of tungsten (W) obtained from the use of 18 grams of hydrogen according to the following equation:

$$WO_3 + 3\,H_2 \rightarrow W + 3\,H_2O$$

(1) 1 x 184 grams
(2) 3 x 184 grams
(3) 9 x 184 grams
(4) 18 x 184 grams
(5) 184 grams + 3 x 16 grams

100. What is the weight of 11.2 liters of nitrogen (N_2) at STP?

(1) 7.0 grams
(2) 11.2 grams
(3) 14.0 grams
(4) 22.4 grams
(5) 28.0 grams

End of Test.

VITA

James Joseph Altendorf

Title: A STUDY OF STUDENT ACHIEVEMENT IN HIGH SCHOOL CHEMISTRY USING CHEM STUDY AND CONVENTIONAL APPROACHES

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Personal Data: Born in Independence, Kansas, February 13, 1928, the son of James P. and Bessie E. Altendorf.

Education: Attended elementary school in Independence, Kansas; graduated from Independence High School in 1946; received the Associate of Arts Degree from Independence Junior College in May, 1950; received the Bachelor of Science in Education Degree, with a major in chemistry, from Kansas State College of Pittsburg in January, 1954; received the Master of Science Degree, with a major in chemistry, in May, 1955; completed requirements for the Doctor of Education degree in August, 1965; received a National Science Foundation College Faculty Fellowship for fifteen months study at Oklahoma State University during 1959-60; selected for the College Faculty Research Participation Summer Program at Oklahoma State University in 1961.

Professional experiences: Enlisted in the United States Navy in 1946; served on active duty at the Naval Air Station, Pensacola, Florida; released to inactive duty status as a Radioman, Third Class in 1948; recalled to active duty in 1951; served on the U.S. LST 1079; released to inactive duty in 1952; discharged from the United States Naval Reserve in 1953; accepted commission, in 1959, to First Lieutenant in the U.S. Army Reserve Chemical Corps; presently hold the position of battalion operations and training officer for the advanced individual training of two infantry companies and two armored tank reconnaissance companies; present permanent rank, captain; appointed to the position of junior chemist with the Ames Laboratory of the Atomic Energy Commission in 1954; appointed instructor in chemistry at Garden City Junior College, Garden City, Kansas, in 1955; appointed instructor of chemistry at El Dorado Junior College, El Dorado, Kansas, from 1956 to 1958; appointed to instructor of chemistry at Southwestern College, Winfield, Kansas, in 1958; rank was increased to assistant professor in 1960 and associate professor in 1965; received tenure in 1963; in the fourth year serving as traveling science consultant speaker for the Kansas Academy of Science College Science Consultant Program; give approximately ten speeches a year to high school science oriented groups.