A STUDY OF THE EFFECT OF SELECTED MULTIPLE-CHOICE ITEMS ON CONCEPTUAL AND FACTUAL ORIENTATION OF STUDENTS IN GENERAL CHEMISTRY

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CHAPTER I

INTRODUCTION

The individual that is able to provide volumes of information on many topics is useful to society in helping solve its many problems. But the individual that has the ability to interrelate many facts and to synthesize these facts into a well defined solution to a problem is even more valuable to society. It is the latter individual that makes the volumes of information accumulated by the human race a worthy venture, for it is this information that becomes the raw material for the solution of perplexing problems.

One who has that capacity to interrelate many facts and synthesize these facts into a meaningful whole is said, among other things, to have demonstrated an understanding of the facts. To be sure the actual synthesis of the facts into a solution of a practical problem includes several mental activities other than understanding. Yet understanding of the interrelation of facts to one another is a necessary beginning to such synthesis.

Down through the ages educational institutions have attempted to insure that their charges have gained and retained some assortment of facts that the institution feels is important. Yet this is certainly not the sole aim of an educational institution. W. H. Chambers (5) writes:

> However important the acquisition and retention of facts may be, it is doubtful that school administrators or teachers

> would ever agree that their efforts in working with students are primarily directed toward these objectives.

An understanding of the import and relation of these facts is also equally acclaimed. Jean Piaget (9) states:

> The principle goal of education is to create men who are capable of doing new things, not simply repeating what other generations have done--men who are creators, inventors, and discoverers. The second goal of education is to form minds which can be critical, can verify, and do not accept everything they are offered. . . . We have to be able to resist individually, to criticize, to distinguish between what is proven and what is not.

If these can be considered primary goals of education today, then an understanding of facts studied is a paramount objective of activities classified as educational.

Increasing emphasis is being placed on the ability to develop facts at one's disposal into a useful, interrelated whole. Norman Gronlund (17) makes the following statement concerning this increasing emphasis:

> These and similar learning outcomes have been variously classified under such general categories as understanding, reasoning, critical thinking, scientific thinking, creative thinking, and problem solving. There is general agreement that these learning outcomes based on the higher mental processes constitute some of the most significant outcomes of education.

The increase in emphasis on higher mental processes has included the development of these processes in the educational objectives of every institution for higher education. The development of these processes also becomes a goal of each course in the institution. Understanding as one of these processes becomes a separate and distinct goal of a course offered by the institution.

Understanding is a major objective of any course and much time is spent in developing understandings within the course. The verbal adherence to this goal, and the time spent in striving for it suggests that this objective be capable of evaluation through testing. This

study is addressed to the assessment of the objective of understanding in a chemistry course.

Background for the Study

The shift in emphasis from that of knowledge to one of understanding in course objectives should be reflected in the examinations used in such a course. Since the major use of these tests are for student certification--the assignment of a letter grade as an indicator of the degree of competence in the course--then this letter grade should also reflect the degree of understanding in the course. However, this is only true in so far as this type of goal can be tested by the examinations used.

Attempts have been made in recent years to assess understanding with paper and pencil tests using the new type test format. Model multiple choice questions were presented as a result of the Eight Year Study reported in the Forty-ninth Yearbook of the National Society for the Study of Education (4). In this study a number of objective tests for measuring complex learning outcomes were developed under the direction of R. W. Tyler. The impact of this study is shown by Englehardt's (11) statement.

> Until recently, most standardized achievement tests have emphasized rather strongly the purely informational goals of instruction. However, more and more tests now require the student to perform various mental tasks rather than only to recall learned facts. This approach to measurement based upon a sound understanding of pupil growth and development, the nature of learning, and individual and group differences, calls for more widespread utilization of the requisite testing techniques.

The study by Bloom (3), Taxonomy of Educational Objectives has also supported the added emphasis of understanding in course tests. The attempted delineation of the various cognitive processes has aided

in the development of test questions specifically designed toward the goal of assessing these processes.

The course tests are also important to the students, if for no other reason than that they are intimately involved with the system of rewards and punishments important to them. The student is usually interested in doing well, and this is reflected in the grades as determined in part by the tests. This suggests that the student should be very interested in doing well on the tests. Tests also indicate to the student those things that are considered important in a course, and therefore should determine to an extent the learnings most profitable to him.

Written course tests have increased in prominence as clues to the portions of the course important to the student. This trend is due to the large sectioning of students in a course forced by increasing enrollments found in most large schools. The test importance is emphasized by the desire on the part of the student to obtain previous tests for study purposes and the proportion of the grade that is dependent on the written tests for its determination.

The above aspects of the development of the importance of the test and the change in emphasis of educational objectives indicates that information is needed on the extent which the goal of understanding can be tested and the degree to which the tests aid in supporting the stated objectives of a course.

Statement of the Problem

Subject to the limitations set forth presently this study attempts to determine if there is a measurable change which occurs in the ability

of students to answer test questions designed to measure knowledge as opposed to those designed to measure understanding as a result of course testing. This study attempts to measure the change that results because of the student's consistent exposure to similar test objectives throughout the course.

A secondary and supporting objective of this study is to determine to what degree a student consciously alters his study techniques and his approach to the course material as a result of continued exposure to a given testing objective. Necessary for the study is the preparation of tests for the chemistry course that are unitary in their cognitive objectives--namely to assess either understanding of chemistry or knowledge of chemistry, the preparation of a final examination for the chemistry course that contained approximately an equal number of questions assessing understanding of chemistry and knowledge of chemistry, and the development of a student survey that would provide a sample of the conscious preparation the students made for the specific type of test they received.

Hypotheses

The hypotheses that guide this study stated in the null form are as follows:

1. There is no difference (at the 0.05 level of confidence) in the mean scores on the questions designed to assess understanding of chemistry by groups receiving knowledge type questions and the groups receiving understanding type questions.
2. There is no difference (at the 0.05 level of confidence) in

the mean scores on questions designed to assess knowledge of chemistry by groups receiving knowledge type questions and the groups receiving understanding type questions.

3. There is no difference (at the 0.05 level of confidence) in the student emphasis on studying and memorizing facts by the groups receiving knowledge type questions and the groups receiving understanding type questions.
4. There is no difference (at the 0.05 level of confidence) in the student emphasis on the study of the interrelation of facts and thinking relating basic concepts of chemistry by the groups receiving knowledge type questions and the groups receiving understanding type questions.
5. There is no difference (at the 0.05 level of confidence) in the student perception of the difficulty of the tests by the groups receiving knowledge type questions and the groups receiving understanding type questions.
6. There is no difference (at the 0.05 level of confidence) in student perception of the immediate source of materials from which the questions for each test were drawn as perceived by the groups receiving knowledge type questions and the groups receiving understanding type questions.

Significance of the Study

This study should help to give an indication of the relative importance of course test questions useful in supporting the objective of knowledge of facts or the objective of understanding of course content. If the knowledge type questions alone produce poor responses to

understanding type questions, the understanding questions should be specifically included in the construction of the test to aid in supporting understanding as a course objective. If understanding questions produce equally successful results on the knowledge questions, perhaps it would be best to reduce the number and weight of the knowledge questions and still support both the understanding and knowledge outcomes of a course. This study may support one of these possibilities.

The effect of test questions themselves in promoting changes in a student's approach to study and his consideration of what is meaningful in a course should be carefully assessed. The effect of the test in directing the student toward attainment of specific objectives will be indicated by this study.

This study will give an indication of the effectiveness of testing for understanding and the testing for knowledge. If understanding is only a term that cannot be quantitatively assessed by the type of test employed in this study, then it would be wise to devise and rely on some more satisfactory means of measurement.

Limitations of the Study

The population used in this study limits the application of the results of this study. Thus the results are limited to the population of students at Oklahoma State University taking Chemistry 115, a beginning chemistry course for students who have not had any formal introduction to chemistry or those students who have a composite score of 17 or below on the ACT test administered by the University. It also includes only those students who complete the entire semester of Chemistry 115.

The study by its nature is also limited to the subject matter of the course as it was assigned and presented in lecture and laboratory sessions. The text material of the course is found in selected chapters of the text by King and Caldwell (24), College Chemistry (see Appendix).

This study is also limited to the cognitive powers that are necessary to answering questions of knowledge or of understanding as these questions are defined later in the study.

The format of the test is a further limitation. Only objective, multiple choice type questions were used in this study and therefore it is confined to conditions that utilize this form of testing.

Clarification of Terms

The following terms have specific meaning in this study.

Student

A person enrolled in Chemistry 115 at Oklahoma State University.

Test

The test is an examination of the objective type composed of questions with a stem and five responses. One of these responses is considered the best and only correct answer. The questions are often referred to as 5-response multiple choice questions.

Knowledge of Chemistry

A student is said to have demonstrated a knowledge of chemistry if he can recall the content, that is, the laws, theories, and other assertions and facts, as they are presented to him in the chemistry course through lecture of text book reading. This definition is similar to one suggested by Nedelsky (29).

Understanding of Chemistry

A student has an understanding of chemistry if he can use the facts, laws, theories, and other assertions and facts in a context or situation that is different from those used in following explicit rules and situations practiced in the chemistry course. Nedelsky (29) suggests a similar definition.

Ability

The series of cognitive processes that are necessary to demonstrate either knowledge of chemistry or understanding of chemistry.

Student Survey

This is an investigator constructed inventory designed to measure the degree to which a student has interacted with the various objectives of the course test as presented to him in the course test questions.

Pilot Study

This refers to the preliminary study conducted during the first semester of the academic year, 1966-67. In this preliminary study test questions were devised and tested in one section of the four sections of Chemistry 115.

Principal Study

This study refers to that carried out during the second semester of the 1966-67 academic year in which successful questions of the pilot study were utilized.

Knowledge Group

These are students in Chemistry 115 who received questions designed to test for knowledge of chemistry throughout their test experiences in

the course.

Understanding Group

This is the group of students who received test questions to sample their understanding of chemistry throughout their test experiences in Chemistry 115.

Basic Assumptions

This study assumes that the tests taken by the students are major motivational factors directing the student's study. These tests are assumed important enough to the student that he will study the test results to aid in directing further study during the course.

It is assumed that the abilities studied--knowledge and understanding of chemistry--can be measured by the use of paper and pencil tests in the format of the objective multiple choice question. It further assumes that there is no high correlation between the abilities tested.

Randomization is assumed to have controlled for the many factors that are not specifically investigated in this study. It is further assumed that factors of intelligence and interest in chemistry will be initially homogeneous due to the selection procedure used in enrolling for Chemistry 115.

The student's educational experience with objective tests and his degree of sophistication in testing as they relate to the abilities pertaining to this study are surely varied. Still the groups may be assumed homogeneous as a result of the method of selection used in choosing the members of the group.

CHAPTER II

REVIEW OF SELECTED LITERATURE

Introduction

Testing as practiced in education is conducted for a variety of purposes. These purposes may be conveniently grouped to include appraisal of individual student achievement, diagnosis of learning difficulties, appraisal of curriculum effectiveness and assessment of general education progress (43). The appraisal of individual student achievement is the prime concern in this study. Appraisal of individual student achievement is used as a major factor of student certification. This appraisal, then, involves the incentives for students to study course material. Its use for certification may also effectively organize course objectives for the student.

Course tests are an important part of the sampling procedures of student behavior. These student behaviors are compared behaviors expected on the basis of course objectives. This comparison is used to determine the grade given the student in a course. In this sampling procedure the student is confronted with questions to which he may respond. The response, it is hoped, indicates a tangible way the extent to which the student has achieved the objectives of the course.

Selected Literature Related to Test Motivation

Since course tests are a sampling of those outcomes that are

considered of paramount importance in the course, they represent in the student view a set of clues that are of value to him in determining the behavior that is expected of him in a course. The impact of these clues is heightened by the systems of reward and punishment attached to such achievement tests.

The effect that results because of the nature of achievement testing is the directing of student learning activities and student goals. In discussing this relationship between educational goals and testing programs, Robert Ebel (10) states:

> Tests can be valuable tools for motivating and directing student achievement if they are good tests and if the students and teachers know of their general nature at the beginning of a course of instruction.

The extent to which a course test has the power to direct learning is emphasized by John Stalnaker (35).

> Pupils adapt their learning to meet the requirements of the test situation. This adaptation is to be expected because the tests are the most tangible clues and most potent single influence in determining the goals of study. The typical pupil is anxious to do well in school work. Parents stress success in school, and the usual incentives to excel are present. Since success in school is measured in terms of marks and since marks are based in a large part on the results of tests, the pupil soon learns that the test is a real hurdle. He therefore directs his learning in the paths which he believes will lead to high grades on the test, and if there are short cuts, he will use them.

At the completion of secondary school training, the student has had repeated experience with educational testing for student achievement. The student is by this time well aware of the variable but important influence that tests have in indication of his educational success.

The power attributed to the test in molding and directing the goals actively sought by both students and teachers has been utilized in curriculum innovations that have currently been prominent at the

secondary level. The test represents a series of tangible examples of the types of activities that are considered desirable as a result of study of material in the course. Ferris (12) indicates the use of tests for this purpose when he speaks of their role in the new curriculums.

> In this sense the tests were conceived as an integral part of the instruction process for the purpose of communicating to the students and teachers, in terms of specific tasks to be performed, the objective of the course. Since students are strongly influenced by tests, because tests are to them the basis of rewards for their efforts, it is essential that attempts to emphasize methods as well as subject-matter coverage be included so that the student is required to demonstrate his knowledge of process or method as well as his knowledge per se.

Implicit in the above statement is the firm belief that the test lends strong support to the impelementation and direction of changes in student behaviors. The test may be considered one of the chief means of implementing these changes. This belief, though intuitively appealing, is only sparsely supported by experimentally verifiable information. At the height of the development of the objective type questions for achievement testing in 1929 Ruch (31) laments:

> It is unfortunate that we have so little direct information as to the motivating effect of examinations. That examinations do have this value has been tacitly agreed but never proved. In spite of this dearth of proved fact, it does seem reasonable to suppose that pupils strive for somewhat greater and somewhat more permanent mastery when they realize that searching examinations may be expected at a later date.

T. H. Schulte (33), in an early investigation of the value of final examinations, compared one group of college classes which expected a final examination with another group of classes that did not expect a final examination. He found the knowledge that there would be a test produced worthwhile results in terms of the higher group scores on the final examination and in terms of the grasp of lecture material.

The study on the effect of short objective tests of college student achievement in psychology was carried out by S. H. Turney (42). The group of students receiving twelve short objective tests did significantly better work than similar students not taking each test.

Paul Terry (40) studied the review techniques of students for differing types of tests. He found that students adapted their methods of study to the type of test they expected to take when told if the test was objective or essay. In this study he found a correlation of 0.04 with the degree of discrimination of the reviewing techniques and intelligence as measured by the Otis Group Intelligence Scale and a negative correlation of 0.07 with the grades in psychology. He concluded: "It seems reasonable to believe that the study behavior is influenced to a significant extent by the teacher's selection of tests."

Terry conducted further studies into the study behavior of students as they studied for three types of objective tests: recall, completion, and true-false types. Samples of each type were given to junior and senior students in a psychology class. They were asked to respond to a series of questions that indicated how they studied for each type of test. He concluded: "The kind of test to be given, if the students know it in advance, determines in large measure both what and how they study." (41).

George Meyer (28) and Douglas and Tallmadge (8) included the essay exam but came to similar conclusions.

Some doubt as to the sweeping nature of these earlier studies into the effects of a test on a student's approach to study is cast by R. Bakan's (2) study reported in 1957. She was interested in the effect of a modified multiple choice item under differing conditions. The

test used is described as a "free choice" type of test--one in which any number of responses could be marked to insure that the correct one was included. Two groups of students in a natural science course were given this type of question. One group was told that their score on the test would be a part of their grade while the other group was told that their grade would not be affected. There was no significant difference in the results of the two group's scores on the tests. She concluded: ". . . students can be motivated by means other than grades."

In this investigator's opinion, the statement by Ruch still is valid at the present time, namely, that there is a deficiency of empirical information supporting the intuitively satisfying contention that the test molds the goals and is instrumental in guiding student learning.

Measuring Abilities with the Objective Test

To determine the effect that tests have in a course in directing the goals and developing the abilities, it is first necessary to determine what it is that course tests are able to measure. Are they able to measure and test only one type of knowledge? Do they only count the number of facts and bits of information in the possession of the testee, or are tests capable of measuring other higher mental processes? Since a person has an ability to remember bits of information, it is not precluded that this individual possesses an equivalent ability to understand these bits of information. This belief is stated by Cronbach (7):

> Two persons may be acquainted with the same facts or principles, but one will be more expert in his understanding, better able to cope with inconsistent data, irrelevant sources of confusion,

> and apparent exceptions to the principle. To measure intellectual competence is to measure depth, connectedness, and applicability of knowledge.

The objective or "new-type" test question which came into prominence in the early 1900's was found to be quite successful in measuring the bits of information possessed by the student. But as this test form began to be used to a greater extent, it became clear that the questions as they were then being used measured little else but recall of facts. There were attempts to show that the test form was not restricted to demonstrating the ability of the student to recall information, but that it had wider applicability to higher mental processes. Attempts were also made to demonstrate that the measurement of recall is not the same as measurement of other higher mental processes.

One of the first studies in this regard was one reported by Ralph Tyler in a book by C. H. Judd entitled Education as a Cultivation of the Higher Mental Processes (23). This study was conducted over a period of several years to explore the relationships between results of a test of recall, a test of recall and application of principles, and a test of interpretation of data. The tests were of the "new-type". Recall had a single best answer multiple choice form, while the application questions and interpretation of data questions were of the many answer multiple choice form. The application and interpretation questions also included considerably longer stems than the recall questions. Sixteen separate studies are reported in which the number of college students ranged from 22 to 684. These studies also ranged over a variety of courses in the natural and social sciences, agriculture and home economics. Three tests, one of each type--recall, recall and application of principle, and interpretation of data--were given to each class.

The correlation coefficients, corrected for attenuation, ranged from 0.33 to 0.54 for each of the three types of tests. The correlations between the tests for recall and the tests for recall and application were somewhat higher than those for recall and for interpretation of data. This was attributed to the greater reliance of the questions in the application of principles test on recall of information. Tyler (23) concludes:

> Memorization of facts frequently fails to result in the development of higher mental processes. If the higher mental processes of application of principle and inference are really to be cultivated, learning conditions appropriate for their cultivation are necessary.

T. E. Raths (30) in his evaluation of the same studies states:

> These findings are substantial justification of the judgment that we must appraise each of these abilities separately; achievement in one is not always accompanied by achievement in the other.

The correlation coefficients among these tests tend to indicate that they are each measuring different aspects of mental processes, but it is not clear from these studies just what these different aspects are.

Scores on two types of tests in a physical science course were compared by Heil (20). He constructed two tests. One was to measure the recall of physical fact and of stated generalization. The other test was to measure the student's ability to apply generalizations to new situations. Here the situation was presented in a stem. The solutions to the situation were presented in a multiple-choice format. A list of generalizations was presented in a multiple-choice format in which more than one answer was correct. A correlation table was constructed to compare the class rank of students on the knowledge of principles test with the class rank of the same students on the application of principles test. A coefficient of correlation of 0.60 was reported.

The correlation reported in this study is much higher than the correlations reported in the Tyler studies. One is led to speculate about this discrepancy. The Tyler study does not appear to attempt a comparison between recall and application while controlling for facts and subject matter that are related to both application and recall questions. In the study by Heil there is an attempt to assess the knowledge of facts and to assess the ability to apply a principle related to the same facts and subject matter. Perhaps this can account for the higher correlation.

In a study reported recently by Haym Kruglak (25), additional insight is gained that may aid in assessing the effect that the form of the responses expected of the student has on an evaluation. Experimentation was conducted using the multiple-choice question format and an open ended test form to assess knowledge of physics terms. Here the correlation between the scores made on the open ended test and the multiple choice test of definitions was positive but low--about 0.37.

The tests that attempt to utilize and measure the higher mental processes are often criticized because it is felt that they are little more than tests of intelligence. Evidence against this criticism has been forwarded by the work of E. M. Glaser (16). Four twelfth grade English classes were given ten weeks of special instruction that was designed to stimulate growth in the ability to think critically. Gains of the composite critical thinking scores were correlated with initial scores on an intelligence test. The correlation was 0.33. This low correlation was interpreted to imply that reasoning tests are not the same as intelligence tests. The correlations are positive but far from perfect even allowing for the imperfect reliability of the test.

The low or high correlation of one test with another in all of these studies is critically dependent on the means of classifying questions in terms of their behavioral outcomes and the conception of what is believed to be the higher mental processes. Tyler (23) conceived of the mental processes involved in testing as recall, application of principles, and interpretation of data. As a result of the Eight Year Study, Smith and Tyler (34) classified the kinds of thinking ability necessary for a test as: the ability to interpret data, the ability to apply principles of science, the ability to apply principles of logic, and an understanding of the nature of proof. Along these lines of classification, rather elaborate questions were constructed. Sample questions are presented in the Forty-Ninth Yearbook of the National Society for the Study of Education (4). These questions also included an elaborate system of scoring in order to facilitate a diagnostic function.

Revised classification of test questions was further refined by Raymond Gerberich (15). An attempt was made to classify test items according to the types of learning outcomes that they would measure. He distinguished ten types of outcomes: skills, knowledge, concepts, understandings, applications, activities, appreciation, attitudes, interests, and adjustments. Sample questions for each outcome are given in many subject matter areas and directed toward high school levels. Of these outcomes he classified skills and knowledge as highly tangible, concepts, understandings, application, and activities as of intermediate tangibility and those that remain as intangible. The tangibility is representative of the difficulty in measuring the given outcomes.

In order to aid in the construction of test items and to insure that these items measured the stated educational objectives, Bloom (3) developed the Taxonomy of Educational Objectives. The approach to classification of test questions is different here. The course objectives are the basis of classification rather than the questions themselves. In this study the objectives were classified into six major categories: knowledge, comprehension, application, analysis, synthesis, and evaluation. In this taxonomical arrangement each category is presumed to be a necessary part of the category that follows it and thus they form an hierarchical order.

Evidence for the workability of such a system of classification has been accumulating. Stanley and Bolton (38) indicate that the classification in the Taxonomy of Educational Objectives can be used with a considerable degree of reliability. They made use of eight graduate students in education to classify the test items found in Gerberich's book. Of all the questions classified from the book, fifty-one percent were assigned to the knowledge category. This probably reflects the rote-knowledge basis of the typical curriculum at the various levels of education. It was found that five or more classifiers agreed on about one-half of the items. Ignoring subcategories, the classification was considerably better but by no means perfect.

In a more extensive study of the applicability of the classification of the Taxonomy, Stoker and Kropp (39) developed two tests of 36 multiple choice questions. A reading passage was presented first followed by nine questions in each of the six major categories of the Taxonomy. One reading passage involved Mendeleev's construction of the periodic chart of the elements, and the other was an article about the

relationships between surface area, cross section, and weight. The questions were submitted to judges for separation into categories of the Taxonomy. The inter-judge agreement was unanimous for 11 out of 36 of the items on each test. On nine of the other items on one test and sixteen items on the other test there was only one judge that disagreed out of the four judges. The conclusion was:

> Thus it would appear that when the Taxonomy serves as a basis for constructing items to measure the behavior described herein, judges can assign the items to the appropriate categories with some accuracy. Lack of complete agreement can be ascribed to at least the following two reasons, both of which have a common basis in that the item writer and the item judge have different notions about the competencies and the problem solving methods used by students for whom the itmes are intended. First, the item writer might prepare an item for an upper level of the Taxonomy, and the rater believes the student will know the answer to the item because of prior knowledge. Second, the item writer might prepare an item to evoke behaviors regarded as "Evaluation" for example but the student might answer the questions by systematically eliminating distractors; thus, the intended process differs from the obtained process.

The study also provided some additional support for the Taxonomy. The scores on the tests of 1000 students showed that as scores improved in the knowledge and comprehension categories, so did the scores in each of the other areas. Correlation matrices were subjected to simplification analysis. The results of these analysis did support the successive complexity concept for the categories of knowledge, comprehension, application and analysis. However, factor analysis did not support the hypothesized structure for the Taxonomy.

In another attempt to apply the Taxonomy to achievement testing, Schmitt, Montean, Winter, and Farr (32) developed seven unit tests for high school chemistry. Each unit test consisted of 50 questions. Categorization in the six areas of the Taxonomy presented some difficulties when constructing the questions, so modifications were required because

of the limited time in constructing so many questions and the difficulty found in writing the questions. They consolidated the categories in the following way:

> Recall: Any item which had been taught in substantially the same form as that in which it appeared in the test, requiring mere resurrection of a particular bit of information. Rephrasing, inversion of sentences, and similar form changes do not remove any item from the recall category.
>
> Comprehension: Any item requiring the application of a principle under circumstances different from those constituting the teaching context of the principle, but in such a form that the correct principle is implied in the question.
>
> Application: Similar to comprehension, but required principle is not implied in the question, so that the student must select the appropriate principle from his repertoire of learning principles as well as apply it correctly. Quantitative problems were considered in this category.
>
> Higher competencies: This category included items which required analysis of a complex situation and subsequent drawing of analytic, synthetic, or evaluative inferences.

After the test questions had been developed and categorized by the above scheme, they were submitted to a panel of judges. There were disagreements in categorizing some of the test items. When these could not be resolved in conference, the item was discarded. Intercorrelation among test items for category combinations of recall, comprehension, application, and higher competencies were all between 0.87 and 0.80. They concluded that "a common factor is influential in determining performance on all four types of items."

Herron (21) compared the Chemical Education Materials Study Course with the conventional high school chemistry course. In an examination constructed for the purpose, items of the test were identified with each of the six categories of the Taxonomy. The five judges used to validate the categorization of the items agreed unanimously on 33 of the 83 items. In the study, students in the various treatment groups

did not perform at the same level on the several sub-tests, indicating that the abilities that were tested did differ. Subtest reliabilities in each of the categories were low, ranging from 0.62 to 0.48.

The problem of validating tests that are designed to evaluate the higher cognitive powers is a difficult one as indicated in a study by Robert McFall (27). For the purposes of this study, the six categories of the Taxonomy were reduced to two: the ability to recall knowledge in a specific field of study and the ability to handle concepts, analyze principles, render judgments, and evaluate material relevant to a specific content area. Evidence for concurrent validity was gathered by comparison of the two subtests with current methods of evaluating student achievement. A positive correlation with the current methods of evaluating student achievement and the test for recall of knowledge was found. A low correlation resulted in the subtest for higher level mental processes and the current methods of achievement evaluation. The current methods used as a criterion were the grades in the courses of similar subject matter (science), total score on the Stanford Achievement Test, and scores on the science section of the Stanford Achievement Test. Correlation between the Otis Quick-Scoring Mental Ability Test and the subtest for recall of knowledge was also reported. It was 0.40. Between the Otis Quick-Scoring Mental Ability Test and the subtest of higher mental processes the correlation was 0.28. The correlation of the two subtests with each other was 0.41. The magnitude of the correlations produced the following reaction from McFall (27):

> A much lower correlation was anticipated. Theoretically, the ability to handle items characteristic of Subtest B (higher mental processes) should not necessarily be related to the facility with which specific knowledge can be recalled. Whether the two parts of the experimental test are measuring

> independent factors and whether the mental abilities required may be related or must be related cannot be determined on the basis of this data.

The data that were collected for concurrent validity supported the hypothesis that were proposed in the study.

The relationship between the higher mental processes as they are learned in different subject matter areas was explored by Edward Furst (13). He found that a student's level of performance in a certain thinking skill in one subject matter area bears little relationship to his performance level in the same skill in another subject matter area. To be more specific, the ability of a student to judge data in the social sciences had little relationship with the student's ability to judge data in the physical sciences.

In a recent report on the Harvard Project Physics Curriculum Development, Winter and Welch (45) report another variation in categorizing questions used in their achievement tests. One dimension of a two dimensional grid included the operations required of students in answering questions. They included: 1) the recall of specifics, 2) the recall or selection of limiting, identifying, applying, or defining conditions, 3) the interpretation of information requiring the application of concepts, laws, theories, or equations without numerical computation, and 4) the computation from data. This categorization was further reduced by grouping two and three above into a single category that was called "applying knowledge". They encountered difficulty in developing unambiguous questions and felt that the multiple choice format was a severe limitation encountered in attempts to make the evaluations they felt necessary. Limitations of the multiple choice format are also reported elsewhere by John Connaly (6), Banesh Hoffmann (22), and Ferris (12).

Cronbach (7) expresses the difficulties encountered related to the disparity between what the test question actually measures and the categorization of the question by an operation it was to measure. He writes:

> The distinction between factual tests and tests of higher mental processes, as elaborated for example in the Taxonomy of Educational Objectives, is of some value in planning tests, although classifying items as measures of knowledge, application, original problem solving, etc., is difficult and often impossible. Whether a given response represents rote, recall, or reasoning depends upon how the pupil has been taught, not solely on the questions asked.

The knotty problem of classification is further documented by Gerberich (15).

> Lines of demarcation between certain pairs of these outcomes and even among a series of several related outcomes cannot be defined precisely. Such factors as the maturity level and educational background of the pupil, the degree of novelty in the item content, or in the material on which the item is based, the specificity or complexity of the item, and many others combine to influence the nature of the outcome tested.

It is obvious that there are many variables in dealing with achievement test questions and a categorization of these questions by the thought processes involved in answering the questions. An investigator should be alert to these variables as an attempt is made to explore the effects of any one or several of these variables in a test situation.

The Learning Set

Directly related to the testing of the higher mental abilities is the determination of the way in which these abilities are utilized by the student in his educational environment. It is assumed that these cognitive abilities present in varying degree are developed in different measure by the stimulus presented by the educational environment and

controlled by the teacher in the classroom.

The concept of learning sets developed by Harlow (18) in his studies of the learning process are the basis for examining the influential effects of repeated learning processes and experiences on the cognitive process. Ausubel (1) refers to a learning set as the current disposition to perform in a particular way. This disposition reflects two conditions: 1) the general methodological sophistication in approaching a given learning task or attacking a given problem and 2) the performance attitude as one begins the particular learning activity. The methodological sophistication that is involved, according to Ausubel, consists of relatively stable cognitive acquisitions that are concerned with the way in which learning is done and is derived from the past experiences. This is assumed to influence the actual content and direction of the ongoing learning activity.

The influence that a learning set should have on the cognitive process is indicated by Wittrock (46). In his studies he found that a learning set increases the probability of the occurrences of certain responses and decreases the probability of occurrences of other responses, usually through selecting directing, or organizing a part of the learning experience.

A. Luchins and E. Luchins (26) investigated some of the effects of set on improvement in problem solving. They summarized their findings by stating that set is increased with the number of set inducing problems, stress, and the specific methods and procedures used to solve problems. Set reduction occurred with an increase in the number of problems requiring direct solutions, mixing the problems solvable by a method with a direct attack, addition of complex details to the

problem, and discussion of the deleterious effect and nature of set with students.

Ausubel's assumptions are the basis for the following definitions proposed by Laurence and Lila Siegel (36). They define a factually set learner as an individual predisposed to learn factual content, and a conceptually set learner as an individual who rejects factual acquisition except as units of information are clustered and interrelated. Preference is given by the conceptually set learner to learning of concepts and principles. The Educational Set Scale which the Siegels developed was designed to indicate the degree to which an individual was conceptually set or factually set.

Another study related to the set concept is reported by Robert Heath (19). Results of the initial attempts to develop an instrument called a Cognitive Preference Test are reported. This test is used to indicate the student's preference for 1) memory of specific facts or terms, 2) practical application, 3) critical questioning of information, and 4) identification of a fundamental principle. The test was run on a representative sample of students in the Physical Science Study Committee course and another representative sample of conventionally taught physics classes in secondary schools. Heath summarizes: "The results seem to show at least one of the new science curriculums (PSSC) produces observably different modes of dealing with the subject matter."

Summary

Studies have been conducted that indicate the motivation effects of a test on the type of study activity students tend to pursue. This motivational effect of the test has been extended to include the

selection of short term educational goals in a given course. Several differing goals involving educational objectives have been indicated by still other studies. Though there is disagreement about the specific classifications of test items in terms of these goals, there is almost always a classification that separates recall from higher mental processes. Finally, the approach that is made to the learning situation by the individual is dicotomized by the utilization of the concept of learning set. Several studies related to this concept have been presented. It is the hope of this investigator that this study will clarify the effect that test motivation has in the identification and direction of student goals.

CHAPTER III

METHOD AND DESIGN

Introduction

This study is an attempt to determine the effect that test questions designed to utilize specific cognitive processes have on the student's success in answering these questions. Secondly, this study attempts to determine if the student consciously responds to this type of questioning by changing the direction and emphasis of his study for a course. This chapter will present the environmental and control conditions important to this study.

Design of the Study

Students in a beginning chemistry course were randomly assigned to one of two separate groups. This randomization, it was assumed, controlled for initial biases such as difference in intelligence, differences in test sophistication, etc., that might have a bearing on the study. Both groups were full participants in all aspects of the course. Differences in groups were due to treatment they received in the testing program. Tests received by each of the two groups required consistently specific but differing cognitive abilities. One group routinely received questions requiring recall of facts while the second group received questions requiring understanding of similar facts, not specifically recall of facts. Each group received tests covering the

same lectures and assigned materials at identical times. However, tests given at the same time differed only in the cognitive abilities they were intended to evoke.

At the conclusion of the course, a final examination (see Appendices) was given covering the course material consisting of two subtests. The subtests constituted the whole of the final examination and consisted of randomly distributed items involving knowledge and items involving understanding questions in approximately equal numbers. Just prior to the final examination, a student survey designed to assess the direction of study toward these cognitive abilities was administered. A measure to assess the change in the factual or conceptual orientation of the group called the Educational Set Scale was also administered at the conclusion of the course. The mean scores on the final examination subtests were compared for differences as were the mean scores for the two groups on the Educational Set Scale. The responses of the two groups on the student survey were also compared.

A pilot study was conducted in the semester immediately prior to the principal study. The same design was utilized in the pilot study to determine both the feasibility of the study and provide for the development of suitable test items in conformity with the study design and definitions.

Setting of the Study

The course chosen for this study and from which the population of this study was drawn is Chemistry 115 at Oklahoma State University. Chemistry 115 was the first of a sequence of two semester courses in introductory college chemistry. Five hours of college credit was

earned when it was successfully completed. It was designed to meet the needs of those students who had no previous formal training in chemistry and who had an ACT composite score below 17. Those students who planned to specialize in chemistry were not included in this course.

The chemistry 115 course was conducted with the following objectives in mind:

1. The student will develop an understanding of the basic concepts utilized in the physical sciences.
2. The student will develop an appreciation of the organizing effect of chemistry concepts on experimental facts as applied in inorganic chemistry.
3. The student will develop an understanding of the concepts of the atomic nature of matter and an appreciation of some implications of the concepts.
4. The student will develop an understanding of the concepts of chemical change.
5. The student will demonstrate an understanding of the states of matter and their functions.
6. The student will be able to recognize and classify inorganic compounds.
7. The student will develop a basic knowledge of some of the practical applications of chemistry.
8. The student will develop an appreciation of some methods of laboratory investigation.
9. The student will develop some basic skills of laboratory measurement in inorganic chemistry.

The achievement of these objectives was demonstrated by answers given to objective test questions and laboratory instructor evaluation.

The content of the course consisted of selected topics designed to provide a basic foundation in the understanding of inorganic chemistry. The content included the topics of atomic theory, periodic law, kinetic theory, nomenclature, stoichiometry and gas laws. Some descriptive chemistry involving oxygen, hydrogen and the halogens was also included.

The organization of the course included three one-hour lectures, one three-hour lab, and a single one-hour recitation session per week for one semester. The large enrollment and limited facilities required sectioning. There were four lecture sections with 21 laboratory and recitation sections in the fall semester; in the spring semester there were two lecture sections and eight laboratory and recitation sections. The responsibility of the lecture sessions was divided between the same two lecturers in both semesters. The responsibility of laboratory and recitation sessions was divided between seven graduate assistants during the fall semester and three of the seven graduate assistants in the spring semester. The investigator was one of the graduate assistants in each of the semesters.

In the recitation sections graduate assistants conducted discussion of the subject matter developed in the lecture sections, reviewed laboratory investigations and provided opportunity for practice in specific problems related to the course. They each constructed eight separate tests in the format of their choosing designed to evaluate learning that took place in the laboratory. The laboratory topics were related to topics developed in that week's lectures.

The testing program, other than that conducted by the graduate laboratory assistants in recitation sections, consisted of the following groups of tests:

Five quizzes: These were unannounced tests that covered subject matter recently developed in lectures. They were timed so they were rather evenly spaced in the semester. They each provided ten points toward the total points for the course. The quizzes were given during the lecture period.

Three minimum attainment tests: These tests were based on subject matter outlined in a study guide specifically provided for the test. The tests each provided a possible 25 points and were also given during the lecture period.

Two one-hour tests: These tests consisted of questions on lecture and study material assigned and discussed in the course prior to the test. They were given to all sections at a specially designated time and in one location. The tests each provided 60 points toward a final point total.

One two-hour final examination: This test sampled material of the entire course and was given in one place and time to all sections. It provided a maximum of 100 points toward a final total.

These tests constituted a maximum of 345 of the total 415 points possible in the course. The other points were accumulated through laboratory recitation tests and laboratory assistant subjective evaluation. The tests that were a major part of this study were the five quizzes, the three minimum attainment tests, the two one-hour tests, and the one two-hour final examination.

Implementation of the Study

The populations in both the pilot and principal study included only those students enrolled in and completing Chemistry 115 by taking the final examination. The population for the pilot study conducted in the fall semester included only those students in the first of the four sections. The population for the principal study consisted of all students enrolled in Chemistry 115 for the spring semester and who completed the course by taking the final examination. The assignment of students to one of the two experimental groups was accomplished in the following way for both the pilot and principal study. Students were placed into the lecture sections in the order in which they enrolled. They were then assigned seats row by row in the lecture section by sex and alphabetical order of their last names. Then the students were placed into one or the other experimental group in alternating fashion according to the column of the seats they occupied. These seats were permanently assigned for all lectures and tests.

An analysis of the population as assigned to each of the experimental groups according to class and college is presented in Tables I through III. They can be considered representative of the total enrollment in Chemistry 115 and they indicate that the procedure for selection is sufficiently random. A comparison of the same tables indicates that the populations of the pilot study and principal study did not differ substantially from one another in terms of class. There does appear to be a difference in the distribution by colleges in the pilot and principal study. The colleges that had a somewhat different representation in the two studies were Agriculture, Arts and Sciences, and Education.

TABLE I

PILOT STUDY: POPULATION DISTRIBUTION BY CLASS AND COLLEGE

College	Freshman	Sophomore	Junior	Senior	Sub-total	
Knowledge Group						
Agriculture	16	6	-	-	22	(35.5%)
Arts and Sciences	6	3	1	1	11	(17.7%)
Business	2	-	-	-	2	(3.2%)
Education	-	2	-	-	2	(3.2%)
Engineering	6	1	-	-	7	(11.3%)
Home Economics	9	6	2	-	17	(27.4%)
Technical Institute	-	-	1	-	1	(1.6%)
Unclassified	-	-	-	-	-	(0.0%)
Sub-total	38 (62.9%)	18 (29.0%)	4 (6.5%)	1 (1.6%)	62	(100.0%)
Understanding Group						
Agriculture	13	6	2	-	21	(28.4%)
Arts and Sciences	9	6	1	-	16	(21.6%)
Business	-	-	-	-	0	(0.0%)
Education	-	1	-	-	1	(1.4%)
Engineering	11	-	-	-	11	(14.9%)
Home Economics	7	10	5	-	22	(29.7%)
Technical Institute	1	1	-	-	2	(2.7%)
Unclassified	-	-	-	1	1	(1.4%)
Sub-total	41 (55.4%)	24 (32.4%)	8 (10.8%)	1 (1.4%)	74	(100.0%)

TABLE II

PRINCIPAL STUDY: POPULATION DISTRIBUTION BY CLASS AND COLLEGE

College	Freshman	Sophomore	Junior	Senior	Sub-total	
Knowledge Group						
Agriculture	9	6	2	-	17	(15.7%)
Arts and Sciences	14	10	3	3	30	(27.8%)
Business	5	2	-	-	7	(6.5%)
Education	11	1	-	-	12	(11.1%)
Engineering	11	1	-	1	13	(12.0%)
Home Economics	14	9	1	1	25	(23.2%)
Technical Institute	2	-	-	-	2	(1.9%)
Unclassified	2	-	-	-	2	(1.9%)
Sub-total	68 (63.0%)	29 (26.9%)	6 (5.6%)	5 (4.6%)	108	(100.0%)
Understanding Group						
Agriculture	17	5	3	-	25	(27.8%)
Arts and Sciences	8	9	4	-	21	(23.3%)
Business	2	-	-	-	2	(2.2%)
Education	4	3	-	-	7	(7.8%)
Engineering	9	-	-	1	10	(11.1%)
Home Economics	9	6	3	-	18	(20.0%)
Technical Institute	4	1	-	1	6	(6.7%)
Unclassified	1	-	-	-	1	(1.1%)
Sub-total	54 (60.0%)	24 (26.7%)	10 (11.1%)	2 (2.2%)	90	(100.0%)

TABLE III

POPULATION DISTRIBUTION FOR COMBINED GROUPS OF PILOT AND PRINCIPAL STUDIES

By Class	Total	Percentage	By College	Total	Percentage
Pilot Study					
Freshmen	80	58.8	Agriculture	43	31.6
Sophomore	42	30.9	Arts and Sciences	27	19.9
Junior	12	8.8	Business	2	1.5
Senior	2	1.5	Education	3	2.2
			Engineering	18	13.2
			Home Economics	39	28.7
			Technical Institute	3	2.2
			Unclassified	1	0.7
				136	
Principal Study					
Freshman	122	61.6	Agriculture	42	21.2
Sophomore	53	26.8	Arts and Sciences	51	25.8
Junior	16	8.1	Business	9	4.6
Senior	7	3.5	Education	19	9.6
			Engineering	23	11.6
			Home Economics	43	21.7
			Technical Institute	8	4.0
			Unclassified	3	1.5
				198	

Course tests pertinent to this study were the quizzes, minimum attainment tests, hour exams and the final examination. All of the items in these tests were of the objective, five-response, multiple choice form in which one answer was considered correct. The final score on each test included a penalty for incorrect responses. The tests of the pilot study were graded by the investigator and returned in the lecture period about one week after the test was given. In the principal study the tests were graded by the graduate instructors and discussed by them in the recitation sections. The returned tests in the pilot and principle studies had both the score and all correct answers indicated. Discussion of the test questions was usually conducted in the recitation section. Students were allowed to keep all tests except the final examination in the pilot study.

Test questions were developed by the investigator in a two dimensional grid. One dimension of the grid included the concepts and ideas to be tested. The second dimension included the classification of the question into a knowledge question or an understanding question. An understanding question and a knowledge question were constructed for each concept in as many of the areas tested as practical. Parallel questions in the two experimental groups was not considered as absolute necessity.

Records were kept of the topics and examples used in lectures or studied by students in assignments. These topics and examples were used in knowledge questions. Specific examples not used in the lectures and assignments but which could have been used as illustrative material for the concepts became the raw material for understanding questions. Also included in the understanding questions were those

questions that required the utilization of several concepts or facts in order to arrive at the correct conclusion. The workability of the constructed questions was assessed by item analysis for difficulty and discrimination. The test papers were ranked in each group, and the upper and lower 27% of the papers were used in the analysis. Questions that were answered correctly by less than 15% of those tested in the pilot study were not considered for use in the principal study. The category of the questions used in the principal study was verified by a panel of judges.

The return of the tests with correct answers to the students created some difficulties in developing test questions. Novelty was an essential ingredient of the understanding type question. Since tests were freely circulated from one semester to another, questions that were novel to the student in the pilot study were no longer likely to be novel to the students in the principal study. Therefore, new variations or new illustrations were used as source material for questions in the principal study. Only in the final examination was this problem alleviated by collecting test booklets from the students along with their answer sheets. In the pilot study these booklets were not returned.

The student survey was an investigator developed survey designed to provide an indication of how the student responded to the test questions in his experimental group. The questions included an assessment of his perception of the objectives of the test questions, of the origins of materials used in test questions, of the type of study considered essential to the preparation for the test, and a perception of the relative difficulty of the tests. The survey used in the pilot

study included questions that were found to provide little support to this study. These questions were not used in the principal study survey.

The Educational Set Scale (36) was utilized in the principal study as externally independent evidence for the bias that may develop as a result of the treatment. It was hoped that the cognitive style favoring a conceptual set would result in the understanding group and a factual set would result in the knowledge group.

Laurence and Lila Siegel developed the Educational Set Scale to provide a forced choice, objectively scored group inventory to assess educational set. Their work in this regard was reviewed in chapter two of this study. Reliability for the test was reported as 0.94 by the split test method. Correlation between test and retest was 0.92. They also reported the function measured by the Educational Set Scale to be relatively independent of cognitive functions assessed by the American College Testing Program (ACT) composite score and some of the Guilford creativity tests.

Since the time available for the test was limited, only a portion of the Educational Set Scale was used. This included the Natural Science, Business, Economics and Social Science sections. The choice of the sections to be used was determined by random selection.

Statistical techniques that were used in this study include the t-test to determine significance between mean scores on the final examination subtests and the Educational Set Scale. Reliability of the subtests was also determined. The Chi-square test was used to test for significant differences in answering the Student Survey.

Summary

This chapter has presented a brief description of the population and sample used in this study. It has included the design of the study and the methods by which the study was implemented. A brief description of the course that was intimately connected with this study was also included. It was noted that the study was limited by interaction between the sample involved in the pilot study and the population of the principal study. The external instrumentation used in the study was reviewed. The hypotheses of this study were tested utilizing the design presented in this chapter.

CHAPTER IV

PRESENTATION AND ANALYSIS OF THE DATA

Introduction

The primary purpose of this study was to determine if test exposure to specifically designed test questions would produce a measurable change in the ability of students to answer test questions designed to assess knowledge as opposed to test questions designed to assess understanding of chemistry concepts. A secondary purpose of this study was to determine if the student perceived the objectives of the specific testing and attempted to alter his study techniques and approach to course material to meet the unitary test objective. This chapter will present the statistical tests and subsequent analysis of the data from the pilot and the principal study. Homogeneity of groups, reliability of the subtests for knowledge and for understanding, and the hypotheses-principal and secondary--are statistically tested.

Statistical Techniques

Parametric statistics were used to test the principal hypotheses of this study. An F-test (44) was used to check the homogeneity of the variance of the knowledge and understanding groups as they were represented by the scores on each subtest of the final examination. An F-test was also used on the scores of the Educational Set Scale. The t-test for pooled variance was used to determine if there was a

significant difference in the groups' subtest mean scores both on the final examination and on the Educational Set Scale.

The reliability of the test scores on each subtest of the final examination was determined by means of the Kuder-Richardson method of rational equivalence (14). This method attempts to estimate the reliability of a test by stressing the intercorrelations of the items in the test and the correlations of the items with the entire test.

Nonparametric statistics were used to analyze the responses to the student survey. Chi-square analysis (37) was used to test for significance of group responses related to the secondary hypotheses. Cells of the contingency tables that have expected frequencies of less than five were combined when they constituted 20 per cent or more of the table.

Findings of the Pilot Study

There were 136 students included in the pilot study. Of these students 62 were in the knowledge group and 74 were in the understanding group. An F-test on the variance of scores on the knowledge subtest for the two experimental groups was 1.07. The F-test for the understanding subtest was 1.19. Since significance at the 0.02 level of confidence requires the F-value to be at least 1.79, it was concluded that there was no significant difference in the variance of the groups for both subtests.

An analysis of the data using the pooled variance t-test gave a t-value of 0.20 for the two experimental groups on the knowledge subtest. The t-value for the two groups on the understanding subtest was 1.60. The 1.60 value is significant at about the 0.10 level. Such a result was considered encouraging.

The student survey items that were significant are summarized briefly. Item 2. "The test questions on the test you took were directly taken from the study guide." The chi-square analysis of the responses to this stem gave a value of 9.09. The group receiving understanding questions responded most frequently to "almost never" and "a few times".

Item 7. "The answers to test questions depended only on the understanding of chemical ideas." The chi-square analysis of the student responses to this stem had a value of 9.84. The knowledge group responded most frequently to "sometimes" while the understanding group responded most frequently to "most often".

Item 19. "How did the difficulty of your test compare with the other form test?" The chi-square value of 27.8 resulted from the analysis of student responses to this stem. Of the two groups the knowledge group responded most frequently to "about the same" or "easier" while the understanding group responded to "much harder".

Because of the favorable results of the subtest scores and the several significant items on the student survey, it was decided to continue with the principal study with a larger group of students. To strengthen the study, the Educational Set Scale was added for the purpose of determining if the approach of the groups to the study of any subject including chemistry was significantly different.

Findings of the Principal Study

The principal study was conducted during the second semester of the academic year, 1966-67. It included all students enrolled in Chemistry 115. The two sections were taught by two different instructors--

Dr. Johnston and Mr. Breedlove. Even though their approaches to topics and students differed, they introduced the same topics to both sections. The Educational Set Scale and the student survey were conducted in the last two lecture hours before the final examination respectively. The final examination was composed of subtest questions on knowledge and understanding of chemistry. They were randomly arranged to make up the final examination. Thus the student was not able to identify the type of question by means of its location in the test booklet. Reliability coefficients for the knowledge and the understanding subtests were 0.83 and 0.80 respectively.

Both experimental groups were considered homogeneous with respect to the variance of their test scores. The F-test gave an F-value of 1.23 for the knowledge subtest. The F-value on the understanding subtest was 1.50. An F-value of 1.54 for 89 and 107 degrees of freedom is significant at the 0.02 level of confidence. The variance of the two groups was considered homogeneous.

The t-test was used to test for significance at the level set in the major hypotheses. Hypothesis 1: There is no difference (at the 0.05 level of confidence) in the mean scores on questions designed to assess understanding of chemistry by groups receiving knowledge type questions and the groups receiving understanding type questions. The t-value obtained (TABLE IV) for the understanding subtest was 0.349. The t-value at the previously set level of confidence should be equal to or greater than 1.98. It was concluded that there is no significant difference in the scores by the two groups on the subtest designed to assess understanding.

TABLE IV

t-TEST OF SIGNIFICANT DIFFERENCE IN SCORES ON QUESTIONS DESIGNED TO ASSESS UNDERSTANDING OF CHEMISTRY

Group	Number N	Mean $\bar{X}$	Sum of squared deviations Σx^2
Knowledge	108	14.694	2714.917
Understanding	90	14.722	3398.056
	t = 0.349		

Hypothesis 2: There is no difference (at the 0.05 level of confidence) in the mean scores on questions designed to assess knowledge of chemistry by groups receiving knowledge type questions and groups receiving understanding type questions. The t-value obtained (TABLE V) for the knowledge subtest for the two experimental groups was 0.475. Since this t-value is below the value needed for the previously set level of confidence it was concluded that there is no significant difference in the mean scores of the two groups on the knowledge subtest.

Hypothesis 3: There is no difference (at the 0.05 level of confidence) in the student emphasis on studying and memorizing facts by the groups receiving knowledge type questions and the groups receiving understanding type questions. Items 4, 9 and 13 were used on the student survey to detect differences in the two groups as stated in this hypothesis.

The chi-square analysis of student response to the survey question 4, "The test questions on the tests you took required only that you remember some memorized facts," resulted in a chi-square value of 12.8.

(TABLE VI). The understanding group responded more often to "almost never" and "a few times" while the knowledge group responded with greater frequency to "often" and "almost always". The probability of this chi-square value is less than 0.01.

TABLE V

t-TEST OF SIGNIFICANT DIFFERENCE IN SCORES ON QUESTIONS DESIGNED TO ASSESS KNOWLEDGE OF CHEMISTRY

Group	Number N	Mean $\bar{X}$	Sum of squared deviations Σx^2
Knowledge	108	17.593	3252.074
Understanding	90	17.200	3332.400
	t = 0.475		

The chi-square analysis of the student response to the survey question number 9, "This course was a challenge to your memorizing ability," resulted in a chi-square value of 10.73 (TABLE VII). The understanding group had the greater response frequency to "almost never" and "a few times" while the knowledge group had a higher response frequency to the "often" and "almost always" categories. The probability of this chi-square value is less than 0.05.

Chi-square analysis of the survey question number 13, "in studying for the tests, how much time was spent in memorizing facts?" resulted in a value of 11.28. (TABLE VIII). The understanding group responded

TABLE VI

CHI-SQUARE ANALYSIS OF STUDENT RESPONSE TO THE QUESTION, "THE TEST QUESTIONS ON THE TEST YOU TOOK REQUIRED ONLY THAT YOU REMEMBER SOME MEMORIZED FACTS"

Group \ Response	Almost never	A few times	Sometimes	Often	Almost always	Totals
				Combined Categories		
Understanding	18	26	23	8		83
Knowledge	7	22	32	22		75
Totals	25	48	55	30		158

Chi-square = 12.8 with 3 degrees of freedom.
Probability less than 0.01.

TABLE VII

CHI-SQUARE ANALYSIS OF STUDENT RESPONSE TO THE QUESTION, "THIS COURSE WAS A CHALLENGE TO YOUR MEMORIZING ABILITY"

Group \ Response	Almost never	A few times	Sometimes	Often	Almost always	Totals
Understanding	8	13	23	21	10	75
Knowledge	1	9	23	30	20	83
Totals	9	22	46	51	30	158

Chi-square = 10.73 with 4 degrees of freedom.
Probability less than 0.05.

TABLE VIII

CHI-SQUARE ANALYSIS OF STUDENT RESPONSE TO THE QUESTION, "IN STUDYING FOR THE TESTS, HOW MUCH TIME WAS SPENT IN MEMORIZING FACTS"

Response / Group	Very little time	Less than ½ time	About ½ time	More than ½ time	Most of the time	Totals
Understanding	11	23	23	10	8	75
Knowledge	3	19	38	18	5	83
Totals	14	42	61	28	13	158

Chi-square = 11.28 with 4 degrees of freedom.
Probability less than 0.05.

with greater frequency to the "very little time" and "less than ½ time" statements. The knowledge group, on the other hand, responded with greater frequency to the "about ½ time" and "more than ½ time" categories.

Since all three questions on the student survey pertaining to hypothesis 3 had a probability of less than 0.05, it was concluded that there is a difference in the student emphasis on studying and memorizing facts by groups receiving knowledge type questions and groups receiving understanding questions. Hypothesis 3 is rejected.

Hypothesis 4: There is no difference (at the 0.05 level of confidence) in the student emphasis on the study of the interrelation of facts and thinking relating basic concepts of chemistry by the groups receiving knowledge type questions and the groups receiving understanding type questions. Items 5, 6, 8 and 14 on the student survey were used to detect differences related to this hypothesis.

Analysis of the response to question 5 on the student survey, "Thinking about facts studied was important in answering test questions," give a chi-square value of 7.57 (TABLE IX). The frequency of the response was greater for the understanding group to the "almost always" response. The response frequency was greater for the knowledge group to the combined categories characterized by "a few times". The chi-square value is significant at the 0.05 level of confidence.

Student responses to items 6, 8 and 14 were not significant at the 0.05 level of confidence. Chi-square analysis for item 6, "Two or more chemical ideas were needed to answer each question." has a value of 3.13 (TABLE X). Item 8, "This chemistry course was a challenge to your thinking ability," had a value of 5.69 (TABLE XI), and item 14, "In

TABLE IX

CHI-SQUARE ANALYSIS OF STUDENT RESPONSE TO THE STATEMENT, "THINKING ABOUT FACTS STUDIED WAS IMPORTANT IN ANSWERING TEST QUESTIONS"

Group \ Response	Almost never	A few times	Sometimes	Often	Almost always	Totals
	Combined Categories					
Understanding		5		20	50	75
Knowledge		13		32	38	83
Totals		18		52	88	158

Chi-square = 7.57 with 2 degrees of freedom.
Probability less than 0.05.

TABLE X

CHI-SQUARE ANALYSIS OF STUDENT RESPONSE TO THE STATEMENT, "TWO OR MORE CHEMICAL IDEAS WERE NEEDED TO ANSWER EACH QUESTION"

Group \ Response	Almost never	ne A few times	Sometimes	Often	Almost always	Totals
	Combined Categories					
Understanding	10		24	28	13	75
Knowledge	10		32	34	7	83
Totals	20		56	62	20	158

Chi-square = 3.13 with 3 degrees of freedom.
Probability less than 0.50.

TABLE XI

CHI-SQUARE ANALYSIS OF STUDENT RESPONSE TO THE STATEMENT, "THIS CHEMISTRY COURSE WAS A CHALLENGE TO YOUR THINKING ABILITY"

Group \ Response	Almost never	A few times	Sometimes	Often	Almost always	Totals
	Combined Categories					
Understanding	3		7	24	41	75
Knowledge	9		14	26	34	83
Totals	12		21	50	75	158

Chi-square = 5.69 with 3 degrees of freedom.
Probability less than 0.20.

studying for the tests, how much time was spent in trying to understand ideas and relations of facts to one another?" had a value of 4.30. (TABLE XII).

Hypothesis 4 is not rejected at the 0.05 level of confidence, since only one of the four questions produced results that were significant.

Hypothesis 5: There is no difference (at the 0.05 level of confidence) in the student perception on the difficulty of the tests by the groups receiving knowledge type questions and the groups receiving understanding type questions. Items 7 and 16 in the student survey were related to this hypothesis.

The obtained chi-square value for item 7, "The test questions on your form were difficult to understand," was 22.28 (TABLE XIII). This value is significant at a confidence level of less than 0.001. The response frequency was greater for the understanding group in the categories characterized by "often". The knowledge group responded with greater frequency to "almost never".

The obtained chi-square value for item 16, "How did the difficulty of your tests compare with the other form tests?" was 107.22 (TABLE XIV). This value is also significant at less than the 0.001 level of confidence. The understanding group responded with greater frequency to the "much harder" category.

From the computed significance it was concluded that there is a difference in the student perception of the difficulty of the two tests and thus hypothesis 5 is rejected.

Hypothesis 6: There is no difference (at the 0.05 level of confidence) in student perception of the immediate source of material from

TABLE XII

CHI-SQUARE ANALYSIS OF STUDENT RESPONSE TO THE QUESTION, "IN STUDYING FOR THE TESTS, HOW MUCH TIME WAS SPENT IN TRYING TO UNDERSTAND IDEAS AND RELATIONS OF FACTS TO ONE ANOTHER"

Response / Group	Very little time	Less than ½ time	About ½ time	More than ½ time	Most of the time	Totals
	Combined Categories					
Understanding	14		20	23	18	75
Knowledge	19		32	17	15	83
Totals	33		52	40	33	158

Chi-square = 4.30 with 3 degrees of freedom.
Probability less than 0.30.

TABLE XIII

CHI-SQUARE ANALYSIS OF STUDENT RESPONSE TO THE STATEMENT, "THE TEST QUESTIONS ON YOUR FORM WERE DIFFICULT TO UNDERSTAND"

Response / Group	Almost never	A few times	Sometimes	Often	Almost always	Totals
Understanding	5	12	31	19	8	75
Knowledge	22	24	24	12	1	83
Totals	27	36	55	31	9	158

Chi-square = 22.28 with 4 degrees of freedom.
Probability less than 0.001.

TABLE XIV

CHI-SQUARE ANALYSIS OF STUDENT RESPONSE TO THE QUESTION, "HOW DID THE DIFFICULTY OF YOUR TESTS COMPARE WITH THE OTHER FORM TESTS"

Group \ Response	Much easier	Usually easier	About the same difficulty	Much harder	No opinion	Totals
	Combined Categories					
Understanding		5		61	9	75
Knowledge		68		3	12	83
Totals		73		64	21	158

Chi-square = 107.22 with 2 degrees of freedom.
Probability less than 0.001.

which the questions for each test were drawn as perceived by groups receiving knowledge type questions and the groups receiving understanding type questions. Items 1, 2, 3 and 12 on the student survey were related to this hypothesis.

The obtained chi-square value for item 1, "Material for test questions on the test you took were directly taken from assignments in the textbook," was 10.52 (TABLE XV). This value is significant at less than the 0.02 level of confidence. The understanding group responded with greater frequency to the "almost never" and "a few times" categories.

None of the other three items had a chi-square value significant at the 0.05 level of confidence. The obtained chi-square value for item 2, "Material for test questions on the tests you took were directly taken from the study guides," was 1.99 (TABLE XVI). The chi-square value for item 3, "Material for test questions on the test you took were directly taken from the lectures," was 2.64 (TABLE XVII), and for item 12, "The chemical substances and reactions used in the test questions were the same as those studied in preparing for the test," the value was 6.62 (TABLE XVIII).

It was concluded that there was no significant difference in the student perception of the immediate source of materials from which the questions for each test were drawn. Hypothesis 6 is confirmed.

Other items on the student survey do not pertain directly to the hypotheses of this study. Analysis of responses to these remaining questions may be found in the Appendix.

The Educational Set Scale was used in the principal study as an independent instrument to evaluate the concept or factual orientation

TABLE XV

CHI-SQUARE ANALYSIS OF STUDENT RESPONSE TO THE STATEMENT, "MATERIAL FOR TEST QUESTIONS ON THE TEST YOU TOOK WERE DIRECTLY TAKEN FROM ASSIGNMENTS IN THE TEXTBOOK"

Group \ Response	Almost never	A few times	Sometimes	Often	Almost always	Totals
	Combined Categories					
Understanding	14		18	27	16	75
Knowledge	3		21	31	28	83
Totals	17		39	58	44	158

Chi-square = 10.52 with three degrees of freedom.
Probability less than 0.02.

TABLE XVI

CHI-SQUARE ANALYSIS OF STUDENT RESPONSE TO THE STATEMENT, "MATERIAL FOR TEST QUESTIONS ON THE TESTS YOU TOOK WERE DIRECTLY TAKEN FROM THE STUDY GUIDES"

Group \ Response	Almost never	A few times	Sometimes	Often	Almost always	Totals
	Combined Categories					
Understanding	9		24	27	15	75
Knowledge	9		19	34	21	83
Totals	18		43	61	36	158

Chi-square = 1.99 with three degrees of freedom.
Probability less than 0.70.

TABLE XVII

CHI-SQUARE ANALYSIS OF STUDENT RESPONSE TO THE STATEMENT, "MATERIAL FOR TEST QUESTIONS ON THE TEST YOU TOOK WERE DIRECTLY TAKEN FROM THE LECTURES"

Group \ Response	Almost never	A few times	Sometimes	Often	Almost always	Totals
	Combined Categories					
Understanding	5		32	27	11	75
Knowledge	5		28	30	20	83
Totals	10		60	57	31	158

Chi-square = 2.64 with three degrees of freedom.
Probability of less than 0.50.

TABLE XVIII

CHI-SQUARE ANALYSIS OF STUDENT RESPONSE TO THE STATEMENT, "THE CHEMICAL SUBSTANCES AND REACTIONS USED IN THE TEST QUESTIONS WERE THE SAME AS THOSE STUDIED IN PREPARING FOR THE TEST"

Response / Group	Almost never	A few times	Sometimes	Often	Almost always	Totals
Understanding	6	12	36	16	5	75
Knowledge	3	11	30	30	9	83
Totals	9	23	66	46	14	158

Chi-square = 6.62 with four degrees of freedom.
Probability of less than 0.20.

of the subjects in this study. The scoring of this instrument, as originally designed, ranges from minus values for factual orientation to zero for neutral orientation and then to positive values for concept orientation. The greater the absolute value of the score, the higher is the degree of set orientation.

In this study all scores on this instrument (ESS) were increased by adding ten points to the raw score of each subject, so that the t-test could be used. In this modified scale neutral orientation is represented by a score of ten, factual orientation by a score less than ten and concept orientation by a score greater than ten. The t-test was used to determine if there were significant differences at the 0.05 level of confidence in the scores of the knowledge groups and understanding groups on the Educational Set Scale.

An F-test on the variance of the scores to the two groups resulted in an F of 1.081 which is not significant at the 0.05 level of confidence. The scores represent a homogeneous group. Table XIX reveals that the mean scores of the two groups could be considered only slightly concept oriented. The t-value for the difference in the means for the knowledge and the understanding groups are not significant at the 0.05 level of confidence.

Summary

Chapter IV has presented a detailed account of the statistical analysis of the data pertaining to this study. The findings were applied to determine the creditability of the stated hypotheses in the study.

The t-test was used to determine if significant differences at the

predetermined levels of confidence existed between the knowledge groups and the understanding groups on the final examination subtests and the Educational Set Scale. Chi-square analysis was used to determine if significant differences existed in responses to the student survey. Application of the analysis resulted in the rejection of two null hypotheses pertaining to the student survey. The two major hypotheses and two other hypotheses related to the student survey were not rejected.

TABLE XIX

t-TEST OF SIGNIFICANT DIFFERENCE IN SCORES ON THE EDUCATIONAL SET SCALE

Group	Number N	Mean $\bar{X}$	Sum of squared deviations Σx^2
Understanding	90	12.00	8702.00
Knowledge	108	11.91	9677.07
	t = 0.042		

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to measure changes in student performance that resulted from continued exposure to specific test objectives involving knowledge of chemistry and understanding of chemistry. Students were exposed to two types of tests. One test type required a demonstration of recall of course content and direct application of learned facts in Chemistry 115. The other test type required a demonstration of understanding of the content of the chemistry course.

A secondary and supporting objective of this study was to determine if the student consciously altered his study techniques and approach to the course materials as a result of the continued exposure to these specific testing objectives.

For the purpose of establishing the feasibility of this study a pilot study was conducted in the fall semester of the 1966-67 school year. The subjects of the study consisted of one section of the four sections taking the chemistry course in the fall. The principal study consisted of all students taking Chemistry 115 (two sections) in the spring of the same academic year.

The design of the study was similar for both pilot and principal studies. The subjects of the study were randomly placed into two groups. One group was given knowledge type questions throughout the

semester; the other group was given understanding type questions. Prior to the final examination a student survey was conducted to assess student perception of test objectives and to determine the student approach to study material for the tests. The final examination was investigator constructed and consisted of test questions of both knowledge and of understanding. The two subtests, one composed of knowledge questions and the other of understanding questions were scrambled in the final examination. The performances of each experimental group were compared for each subtest of the final examination. The responses to the student survey by the two groups were also compared. The Educational Set Scale was also used in the principal study to provide an external measure of the conceptual or factual bias of the two groups. With the exception of the test questions used during this study, the chemistry classes were conducted in the normal lecture-recitation-laboratory routine of college teaching.

Reliability coefficients, Chi-square and t-tests for significance were used to analyze the resulting data. The null hypotheses were then confirmed or rejected on the basis of this analysis.

The instruments that constituted the treatments as well as the final test instrument were all investigator constructed. The Educational Set Scale was the only external instrument used.

Conclusions

Factor analysis of educational objectives suggests a hierarchy of cognitive powers. This hierarchy begins with cognitive powers basic to recall. Higher cognitive powers are involved in application and problem solving. The knowledge type questions of this study may be

correlated with recall while the understanding type questions with some of the higher cognitive powers in the hierarchal order. When applied to this study, the hierarchy would suggest that there should be a significant difference in the mean scores of the knowledge and the understanding groups on the understanding type questions and no significant differences in the mean scores on the knowledge type questions. This anticipated result was not substantiated by the principal study. The pilot study did indeed show this trend, but not at the present level of confidence.

Subject to the limitations of this study, the following conclusions were drawn.

1. There was no significant difference in the mean scores of questions designed to assess understanding of chemistry by the groups receiving knowledge type questions and the groups receiving understanding type questions.
2. There was no significant difference in the mean scores of questions designed to assess knowledge of chemistry by the groups receiving knowledge type questions and the groups receiving understanding questions.
3. There was no biasing of either of the groups toward a factual or conceptual orientation.

None of the primary hypotheses were rejected in the null form.

The student survey which was used to assess the student reactions to the treatments produced mixed results. Significance resulted in a greater number of questions in the principal study than in the pilot study. The following conclusions were drawn on the basis of the student survey.

1. There is no difference in the student emphasis on the study of the interrelation of facts and thinking relating basic concepts of chemistry by the groups receiving knowledge type questions and groups receiving understanding type questions.
2. There is no difference in student perception of the immediate source of material from which the questions for each test were drawn as perceived by the groups receiving knowledge type questions and the groups receiving understanding type questions.

Some interaction between test question type and the experimental groups did occur, since the following conclusions are supported by this study.

1. There is a significant difference in the student emphasis in studying and memorizing facts by the groups receiving knowledge type questions and the groups receiving understanding type questions. When questions were based primarily on understanding little memorizing is done by students. This is true even if the questions are in the multiple choice format.
2. There is a significant difference in the student perception of the difficulty of the test by the groups receiving knowledge type questions and the groups receiving understanding type questions. The understanding group considered their tests to be much more difficult.

Some change in the student approach to material on the tests was indicated by significant differences in thinking about facts. The thinking about facts was consciously attempted by those receiving understanding type questions. Despite this conscious effort by the students,

it is the opinion of the investigator that thinking about the interrelation of facts and chemical concepts in studying material of the course was done in an ineffective way for answering the understanding type questions. Therefore the tests must be supported in other ways to make effective the study for understanding.

Within the limitations of this study, specific emphasis of higher cognitive powers on the separate tests did not produce significant differences in answering questions involving those higher cognitive powers. The understanding questions did seem to create a sense of insecurity in the students receiving that type of test. This feeling may well have led to a sense of frustration and interfered with the challenge of the questions. It is clear from this study that tests, important as they are, do not change conceptual or factual orientation in one semester.

Recommendations

Basic to the improvement of all teaching and specifically chemistry teaching is the evaluation of basic assumptions of current educational practice and innovation. The following suggestions are in the interest of this improvement.

1. Studies similar to this study should be conducted over a longer period of time to determine the student adjustment that may take place in student orientation.
2. Since the population in this study was only a small segment of those students taking chemistry, studies should be conducted using students with science orientation.
3. Studies should be conducted on populations exposed to test questions incorporating higher cognitive powers while

controlling statistically for factual or concept orientation.

4. Studies should be conducted on factual and conceptual orientation with course materials specifically designed with facts or concepts as a prime objective.
5. Studies should be conducted to determine the extent to which student uneasiness interferes with the learning process.

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APPENDIX A

SCHEDULE OF TESTS

SCHEDULE OF

TESTS FOR CHEMISTRY 115

Test for the course: King, Brooks and W. Caldwell. College Chemistry, 4th ed., New York: American Book Co., 1963.

Chapters assigned during the semester in the text.

Chapters 1-8, 11-15, 17, and 22.

Test Schedule

Pilot Study				Principal Study			
Week	Quiz	Minimum Attainment Test	One Hour Exam	Week	Quiz	Minimum Attainment Test	One Hour Exam
1				1			
2				2			
3	x			3	x		
4				4			
5		x		5		x	
6				6			x
7			x	7			
8				8	x		
9	x			9	x		
10	x	x		10	x	x	
11	x			11			
12	x			12	x		
13		x		13		x	
14			x	14			x
15	Final Examination			15	x		
				16	Final Examination		

APPENDIX B

PILOT STUDY

FINAL EXAMINATION AND STUDENT SURVEY

SEAT #_____ NAME_____ LAB DAY M T W TH F S
(LAST) FIRST) LAB INSTRUCTOR_____

CHEMISTRY 115
FINAL EXAMINATION
FORM K

DIRECTIONS: There is one best answer for each question. For each question, blacken the space on the answer sheet that corresponds with the number of that best answer. Be sure to place your lab instructor's name and the Form letter on your answer sheet.

1. Which of the following measurements takes on greater meaning when the atmospheric pressure is known?
   1. heat of fusion
   2. surface tension
   3. melting point
   4. heat of vaporization
   5. boiling point

2. The metallic bond is strongest in the
   1. active metals
   2. group II A metals
   3. transition metals.
   4. halogens
   5. metalloids

3. The high boiling point of water is due to
   1. the polar nature of the water molecule
   2. the hydrogen bonding.
   3. the "bent" nature of the water molecule
   4. 1 and 2
   5. 1, 2 and 3

4. The current ideas of the combustion reaction rests on ideas first forwarded by
   1. Cavendish
   2. Dalton
   3. Priestley
   4. Mendeleev
   5. Lavoisier

5. Molecules of oxygen have the formula
   1. 0 and 0_2
   2. 0_2 and 0_3
   3. 0^{-2} and 0_3
   4. 0^{-2} and 0^{-3}
   5. 0^{-2} and 0_2

6. Which of the following statements is not true about acids that form -ite salts?
   1. The acid contains an acid former and one other element
   2. The acid ends in -ous
   3. The acid former is in a lower oxidation state
   4. They must contain oxygen
   5. They contain hydrogen

7. Phosphoric acid has been partially neutralized if a product of the reaction with sodium hydroxide includes
   1. NaH_2PO_4
   2. Na_2HPO
   3. Na_3PO_4
   4. Na_3PO_3
   5. 1 or 2

8. The sum of the coefficients of the balanced equation below is

   $$CO_2 + NaOH \rightarrow$$

   1. 3 2. 4 3. 5 4. 6 5. none of the answers given

9. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

10. Five moles of hydrogen are produced in the reaction of sodium and water. How many grams of water have reacted? (Na = 23)
1. 18g. 2.90g. 3. 180g. 4. 230g. 5. none of the answers given

11. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

12. Magnesium ions have the same number of electrons as each of the following except,
1. Ne 2. Na^{+} 3. F^{-} 4. O^{-2} 5. Ca^{+2}

13. 10 liters of a gas are collected at 40°C and 600 mm. What is the value of the gas at S.T.P.

1. $V_2 = 10 \times \frac{600}{760} \times \frac{313}{273}$
2. $V_2 = 10 \times \frac{600}{760} \times \frac{273}{313}$
3. $V_2 = 10 \times \frac{600}{760 \times 20}$
4. $V_2 = 10 \times \frac{40 \times 600}{760}$
5. none of the answers given

14. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

15. Which of the following combinations of elements should not be expected to react with each other?
1. Si and O
2. Fr and Ne
3. Cl and Br
4. Na and F
5. Fe and P

16. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

17. Which of the following combinations of atoms contain the greatest number of electrons gained from some other substance?
1. SO_4^{-2} 2. H_2O 3. NH_4^{+} 4. O_2 5. SO_2

18. The electron dot symbol for O^{-2} is
1. $[\cdot\ddot{O}\cdot]^{-2}$ 2. $[\ddot{O}]^{-2}$ 3. $[\cdot O\cdot]^{-2}$ 4. $[O\cdot]^{-2}$
5. $[\ddot{O}]^{-2}$

19. The oxidation number of nitrogen is 3 in a compound of only oxygen and nitrogen. The simplest ratio of oxygen to nitrogen in the compound is
1. 1:2 2. 1:1 3. 3:2 4. 5:2 5. 1:3

20. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

21. Of what value was the rejection of the plogiston theory to science?
    1. It demonstrated that not all problems can be solved experimentally.
    2. It demonstrated that reasoning makes experimentation less important.
    3. It demonstrated the necessity of evaluating ideas in the light of experimental facts.
    4. It showed that even the most complex phenomena can be explained by science.
    5. It proved the importance of electrons in understanding oxidation.

22. In chemistry, a mole is
    1. the number of hydrogen atoms in 18 grams of H_2O.
    2. 6.02 billion particles.
    3. a small animal.
    4. a beauty mark.
    5. the number of carbon atoms in 44 g. of CO_2.

23. The multivalence characteristics of transition metals can best be understood by taking into account unfilled
    1. f orbitals. 4. s orbitals.
    2. s and p orbitals. 3. p orbitals. 5. d orbitals.

24. The correct formula for calcium sulfite is
    1. Ca_2S 2. CaS 3. Ca_2SO_3 4. $CaSO_4$ 5. $CaSO_3$

25. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

26. The electron dot symbol for a chlorine atom is
    1. :Cl: 2. :Cl: 3. :Cl: 4. Cl 5. Cl•

27. At one atmosphere external pressure, the vapor pressure of liquid water
    1. is equal to the heat of vaporization.
    2. may be greater than the external pressure. 4. is 760 mm.
    3. depends on the temperature. 5. is 100°C.

28. The best example for a molecule that is covalently bonded is
    1. NaH 2. HCl 3. BaO 4. NaCl 5. Li_2O

29. The most active metallic element is
    1. Li 2. Na 3. Al 4. Fr 5. Fe

30. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

31. Lithium and chlorine form a compound with
    1. metallic bonding. 4. covalent bonding.
    2. hydrogen bonding. 3. ionic bonding 5. coordinate bonding.

32. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

33. The most abundant element (by weight) in the earth's crust is
1. aluminum.
2. iron.
3. silicon.
4. oxygen.
5. none of the answers given.

34. Which of the following products are formed from the reaction of $Zn(OH)_2$ and NaOH?
1. an acid and water.
2. a gas and an oxide
3. salt
4. none of these answers.
5. water and a salt.

35. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

36. What is the reducing agent in the following reaction?
$Al + H_2 \rightarrow AlH_3$
1. aluminum hydride.
2. aluminum metal.
3. hydride ion.
4. hydrogen gas.
5. aluminum ion.

37. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

38. According to the kinetic theory, the average kinetic energy of a solid and a liquid may be compared by measuring
1. the speed of the individual particles.
2. the heat in one molecule of each substance.
3. the temperature of the two substances.
4. the heat of crystallization of the two substances.
5. the masses of the particles making up the substances.

39. The number of molecules of two gases are the same when the volumes, pressures and temperatures of the two gases are the same. This is a statement of
1. Charles law.
2. the law of definite proportions.
3. the law of multiple proportions.
4. Avogadro's law.
5. Boyles law.

40. A substance that gains electrons in a chemical reaction has reacted with
1. an oxidizing agent.
2. a reducing agent.
3. a catalyst.
4. an acid.
5. a base.

41. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

42. How many grams of carbon dioxide are produced from 18 grams of carbon (C = 12)?
1. none of the following answers.
2. 12 g.
3. 66 g.
4. 88 g.
5. 44 g.

43. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

44. The correct name for SO_2 gas is
1. sulfurous acid.
2. sodium oxide.
3. sulfite.
4. sulfur dioxide.
5. sulfurous oxide.

45. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

46. On heating, PbO_2 yields oxygen. How many moles of PbO_2 are necessary to make 64 g. of oxygen? (Pb = 207)
1. 1/2 mole. 4. 478 moles.
2. 2 moles. 3. 4 moles. 5. none of the answers given.

47. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

48. Se contains 6 electrons in the outer energy level. H_2Se can then be expected to be
1. tetrahedral. 4. polar.
2. ionically bonded. 5. pyramid shaped molecule.
3. a base in water.

49. FeO does not react with water while BaO does. FeO can be classified as
1. an acid anhydride. 4. 1 and 3.
2. a basic anhydride. 3. an oxide. 5. 2 and 3.

50. An amphoteric substance
1. reacts with acids. 4. 1 and 2.
2. reacts with bases. 3. is an oxide. 5. 1, 2 and 3.

51. The orderly repetition of similar chemical properties of the elements depends on
1. isotopes. 4. protons.
2. ions. 3. neutrons. 5. electrons.

52. It is possible for chlorine gas to act as
1. a reducing agent. 4. 1 and 2.
2. an oxidizing agent. 3. an acid anhydride. 5. 1, 2 and 3.

53. Which of the following compounds has a name ending in -ide?
1. $CaCO_3$ 2. $HClO_4$ 3. Na_2SO_3 4. $CaSO_4$ 5. NH_4OH

54. In which of the following compounds does phosphorus have the same oxidation number as in $H_4P_2O_7$?
1. PH_3 2. Na_3PO_4 3. HPO_2 4. H_3PO_3 5. $NaPO_2$

55. The elements W, X, Y, and Z are arranged in order of increasing electronegativity. The compound of the above elements that best represents a covalent bonding is
1. XY 2. Y_2 3. WY 4. WZ 5. X_2Z

56. Oxidation of HBr will always produce
1. O_2 2. H_2 3. Br_2 4. H_2O and Br_2 5. Br^- and H_2

57. The term "halogen" means
1. bad air. 4. stench.
2. acid former. 3. salt former. 5. hydrogen containing.

58. A compound is composed of three elements. The compound cannot be
1. an acid. 4. an oxide.
2. a base. 3. a salt. 5. 1 and 2.

59. The molecular weights of gases A and B are 16 and 64 respectively. The diffusion rate of A is
1. 1/2 that of B. 4. 4 times that of B.
2. 1/4 that of B. 5. none of the answers given.
3. twice that of B.

60. A base is any compound that
1. contains hydrogen. 4. accepts protons.
2. accepts electrons. 3. gives protons. 5. gives electrons.

61. A neutralization reaction of an acid anhydride will always produce
1. an acid. 4. a salt.
2. water. 3. a base. 5. a salt and water.

62. The acid properties of a compound in water solution is due to the presence of
1. H^+ 2. H_3O^+ 3. H_2O^+ 4. HO^- 5. H_2^+

63. Which of the following is an acid salt?
1. CaO 2. $NaHCO_3$ 3. $Ca(OH)_2$ 4. $CaCl_2$ 5. CaOHCl

64. In which of the following reactions does reduction occur?
1. $C + O_2$ 4. $Na_2O + H_2O$
2. $NaF + H_2SO_4$ 3. $BaCO_3$ 5. $NaCl + AgNO_3$

65. H_2 can be released from strong acids by using (both must produce H_2)
1. Zn or Cu. 4. Na or Cl.
2. Fe or Cu. 3. Al or An. 5. Cu or Al.

66. Ammonia is made from hydrogen and nitrogen gas. If 60 liters of ammonia are made then how many liters of hydrogen was used? All gases are measured at 2 atmospheres and 0°C.
1. 9 x 22.4 liters. 4. 20 liters.
2. 90 liters. 3. 30 liters. 5. none of the answers given.

67. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

68. Which of the following is a basic anhydride?
1. Na_2CO_3 2. Na_2O 3. NaH 4. $Ba(OH)_2$ 5. SO_2

69. Which of the following ions is larger than Cl^- ion?
1. magnesium ion. 4. sulfide ion.
2. oxide ion. 3. fluoride ion. 5. potassium ion.

70. Pb, Ca and Mg can be arranged in an activity series by comparing their reactions with water. The order of reactivity (greatest to least) is
1. Ca, Mg, Pb
2. Pb, Ca, Mg
3. Mg, Ca, Pb
4. Mg, Pb, Ca
5. none of the answers given.

71. Hydrogen gas may be liquified under pressure and when cooled. This behavior is explained by using idea of
1. hydrogen bonding.
2. polar bonding.
3. ionic bonding.
4. covalent bonding.
5. Van der Waal's forces.

72-75 relate to the diagram of atom X that showed how subshells are occupied.

(X) 2 2 6 2 3

72. The total number of orbitals occupied by electrons is
1. 10 2. 12 3. 7 4. 8 5. 9

73. The total number of electrons in the 4th major energy level is
1. 11 2. 5 3. 3 4. 2 5. 0

74. The total number of unpaired electrons is
1. 4 2. 0 3. 1 4. 2 5. 0

75. The total number of valence electrons is
1. 1 2. 2 3. 3 4. 5 5. none of these answers.

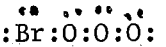
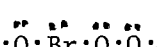
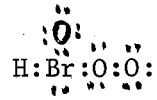
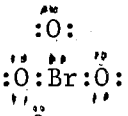
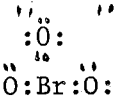
76. The greatest number of electrons in the d sublevel is
1. 2 2. 4 3. 6 4. 7 5. none of these answers.

77. The atomic mass number for an atom is numerically equal to the number of
1. electrons.
2. neutrons.
3. protons.
4. protons plus electrons.
5. protons plus neutrons.

78. Which expression gives the weight of 2 moles of identical gas particles?
1. none of the following answers is correct.
2. Avogadro's number x 2 x the weight of one particle of the gas.
3. Avogadro's number x 2.
4. $\frac{\text{Avogadro's weight}}{2} \times 22.4$
5. 2 x the weight of one particle of the gas.

79. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

80. The electron dot symbol for $HBrO_3$ is

1. 
2. 
3. 
4. 
5. 

81. Individual atoms of the same element always contain the same number of
1. electrons.
2. neutrons.
3. protons and electrons.
4. protons and neutrons.
5. protons.

82. The temperature at which the vapor pressure of a liquid is the same as the external pressure is the
1. melting point.
2. boiling point.
3. surface tension.
4. hydration point.
5. barometric pressure.

83. The atomic particles that have an amu of zero are
1. neutrons.
2. electrons.
3. protons.
4. protons and neutrons.
5. protons and electrons.

84. A test for chloride ion requires the use of
1. $AgNO_3$ 2. HNO_3 3. NH_4OH 4. 1 and 2 5. 1, 2 and 3

85. An odd number of electrons is found in
1. HClO 2. Cl_2O 3. Cl_2O_7 4. ClO_2 5. HCl

86. Barium reacts with sulfur or oxygen. The two compounds that are formed are
1. an acid and an oxide.
2. an acid anhydride and an oxide.
3. a salt and a basic anhydride.
4. an acid anhydride and a basic anhydride.
5. two salts.

87. The formula for a compound is XY_2. X is 20% of the compound by weight. If the atomic weight of X is 30, then the atomic weight of Y is
1. 160 2. 120 3. 80 4. 60 5. none of these answers

88. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

89. Pure hydrogen bromide can be prepared from
1. NaBr and H_2SO_4
2. NaBr and HCl
3. PBr_3 and H_2O
4. 1 and 2
5. 1 and 3

90. How many moles of molecules are there in 22.4 liters of gas at 3 atmospheres and 273°C?
1. 6 moles 2. 3/2 moles 3. 1 mole 4. 2/3 moles
5. none of these

91. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

92. The number of atomic particles that can be exactly determined from the formula, HCl, is the number of
1. protons, neutrons and electrons.
2. protons, and electrons.
3. neutrons.
4. electrons.
5. protons.

93. The non-metallic element that is a liquid at room temperature is
1. Hg 2. Br_2 3. I_2 4. F_2 5. Cl_2

94. A white crystalline substance melts below 100°C. It does not conduct electricity either as a solid or when melted. The substance is most likely
1. an ionic compound.
2. a pure metal.
3. a sodium halide.
4. a crystal made of covalent bonds.
5. a crystal of covalent molecules.

95. Which compound is polar"
1. N_2 2. H_2 3. CCl_4 4. CO_2 5. H_2S

96. 5 liters of a gas are collected at 10°C and 2 atmospheres. How many moles of gas have been collected?

1. $5 \times 2 \times \frac{283}{273}$
2. $\frac{5}{22.4} \quad \frac{2}{1} \quad \frac{273}{283}$
3. 5×2
4. $\frac{5}{22.4}$
5. none of these answers.

97. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

98. How much heat is needed to change 10 grams of ice at -10°C to water vapor at -10°C?
1. 540 calories
2. 5400 calories
3. 6200 calories
4. 100 calories
5. none of these answers

99. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

100. HCl is made in the laboratory from
1. $NaHSO_4$ and NaCl.
2. Na_2SO_4 and NaCl.
3. NaOH and NaOCl.
4. NaCl and H_2O.
5. NaCl and H_2SO_4.

SEAT #______ CHEMISTRY 115 STUDENT SURVEY

PLEASE NOTE: This is not a test. The purpose of this survey is to gather information that will help improve Chemistry testing. To do this we need your help. Above all, we need honest, thoughtful answers.

This survey will NOT be used in any way for determining your grade in this course.

DIRECTIONS:
1) Read each statement carefully and place tne NUMBER of the answer nearest your opinion in the space to the left of the statement.
2) There are NO RIGHT OR WRONG ANSWERS. An answer is right if it is true for you.
3) Be sure to answer every item; do not omit any item.
4) This survey concerns itself only with THEORY QUIZZES, MINIMUM ATTAINMENT TESTS (MAT), and HOUR EXAMS IN Chemistry 115.

- -

_____ 1. The test questions on the tests you took were directly taken from assigned text material
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 2. The test questions on the tests you took were directly taken from the study guide
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 3. The test questions on the tests you took were directly taken from the lecture notes
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 4. Facts were important in answering test questions you took.
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 5. Thinking about facts studied was important in answering test questions
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 6. The answers to test questions depended only on facts that had to be memorized
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 7. The answers to test questions depended only on the understanding of chemical ideas
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 8. The letter grading on the test you took were fair
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 9. The quiz sections helped you in preparing for the tests
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 10. The laboratory periods helped you in preparing for the tests
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 11. This chemistry course was a challenge to your thinking ability
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 12. This chemistry course was a challenge to your memorizing ability
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 13. The tests reflected lecture and assigned material
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 14. Your test score reflected your understanding of the Chemistry you studied
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 15. How often did you compare your color test forms with the other color test form?
1. never. 4. often.
2. a few times. 3. sometimes. 5. every time.

_____ 16. How did the score you thought you got on each test compare with the score you actually made: The score you actually made was
1. almost always lower.
2. sometimes lower. 4. sometimes higher.
3. usually the same. 5. almost always higher.

_____ 17. In studying for the tests, how much time was spent in memorizing facts?
1. very little time.
2. less than 1/2 time.
3. about 1/2 time.
4. more than 1/2 time.
5. most of the time.

_____ 18. In studying for the tests, how much time was spent in trying to understand ideas and relations of facts to one another?
1. very little time.
2. less than 1/2 time.
3. about 1/2 time.
4. more than 1/2 time.
5. most of the time.

_____ 19. How did the difficulty of your tests compare with the other form tests? Your form was
1. much easier.
2. usually easier.
3. about the same difficulty.
4. much harder.
5. no opinion.

APPENDIX C

PRINCIPAL STUDY

FINAL EXAMINATION AND STUDENT SURVEY

CHEMISTRY 115
FINAL EXAMINATION
FORM A

NAME_____ LAB INSTRUCTOR_____

DIRECTIONS: There is one best answer for each question. Select the answer and mark your answer sheet. Also mark your question sheets for your record. YOUR LABORATORY INSTRUCTOR'S NAME MUST ALSO APPEAR ON YOUR ANSWER SHEET .....SCORE = W/4

1. In the reaction: $Br_2 + H_2O$ HBr + HOBr, the bromine gas is
   1. a reducing agent.
   2. an oxidizing agent.
   3. an acid anhydride.
   4. both 1 and 2.
   5. 1, 2 and 3.

2. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

3. In which of the following compounds does phosphorus have the same oxidation number as in $H_4P_2O_7$?
   1. H_3PO_3 2. HPO_2 3. $NaPO_2$ 4. Na_3PO_4 5. PH_3

4. The elements W, X, Y and Z are arranged in order of increasing electronegativity. The compound of the above elements that best represents a covalent bonding is
   1. WY 2. X_2Z 3. WZ 4. Y_2 5. XY

5. Oxidation of HBr will produce
   1. Br^- and H_2 2. H_2O and Br_2 3. Br_2 4. H_2 5. O_2

6. The term "halogen" means
   1. bad air.
   2. salt former.
   3. acid former.
   4. hydrogen containing.
   5. stench.

7. A compound is composed of three elements. The compound cannot be
   1. an acid.
   2. a base.
   3. a salt.
   4. an oxide.
   5. 1 and 2.

8. The molecular weights of gases A and B are 16 and 64 respectively. The diffusion rate of A is
   1. 1/4 that of B.
   2. 1/2 that of B.
   3. twice that of B.
   4. 4 times that of B.
   5. none of the answers given.

9. A base is any compound that
   1. gives protons.
   2. accepts protons.
   3. gives electrons.
   4. accepts electrons
   5. contains hydrogen.

10. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

11. A neutralization reaction of an acid anhydride will always produce
1. a base.
2. a salt.
3. a salt and water.
4. water.
5. an acid.

12. The acid properties of a compound in water solution is due to the presence of
1. H_2^+ 2. H^+ 3. H_3O^+ 4. H_2O^+ 5. HO^-

13. Which of the following is an acid salt?
1. CaOHCl 2. $CaCl_2$ 3. $Ca(OH)_2$ 4. $NaHCO_3$ 5. CaO

14. In which of the following reactions does reduction occur?
1. $BaCO_3$
2. $Na_2O + H_2O$
3. $NaCl + AgNO_3$
4. $C + O_2$
5. $NaF + H_2SO_4$

15. H_2 can be released from strong acids by using (both must produce H_2)
1. Al or Zn
2. Na or Cl
3. Cu or Al
4. Fe or Cu
5. Zn or Cu

16. Ammonia is made from hydrogen and nitrogen gas. If 60 liters of ammonia are made, how many liters of hydrogen was used? All gases are measured at 2 atmospheres and 0^oC.
1. 10 liters.
2. 30 liters.
3. 90 liters.
4. 9 x 22.4 liters.
5. none of the answers given.

17. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

18. Which of the following is a basic anhydride?
1. NaH 2. $Ba(OH)_2$ 3. SO_2 4. Na_2CO_3 5. Na_2O

19. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

20. Pb, Ca and Mg can be arranged in an activity series by comparing their reactions with water. The order of reactivity (greatest to least) is
1. Mg, Pb, Ca
2. Mg, Ca, Pb
3. Pb, Ca, Mg
4. Ca, Mg, Pb
5. none of the answers given.

QUESTIONS 21-24 relate to the diagram of atom X that showed how sub-shells are occupied.

(X) 2 2 6 2 3

21. How many orbitals are occupied by the last three electrons (outer electrons)?
1. 1 2. 2 3. 3 4. 4 5. more than 4 orbitals

22. The total number of electrons in the 4th major energy level is
1. 0 2. 2 3. 3 4. 5 5. 11

23. The total number of unpaired electrons is
1. 1 2. 2 3. 3 4. 4 5. 0

24. The total number of valence electrons is
1. 1 2. 2 3. 3 4. 5 5. none of these

25. The greatest number of electrons in the d sublevel is
1. 2 2. 4 3. 6 4. 7 5. none of these

26. The atomic mass number for an atom is numerically equal to the number of
1. protons. 4. protons plus neutrons.
2. electrons 3. neutrons. 5. protons plus electrons.

27. Which expression gives the weight of 2 moles of identical gas particle?
1. 2 x the weight of one particle of the gas.
2. $\frac{\text{Avogadro's weight}}{2} \times 22.4$
3. Avogadro's number x 2.
4. Avogadro's number x 2 x the weight of one particle of the gas.
5. none of the answers given.

28. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

29. Individual atoms of the same element always contain the same number of
1. protons. 4. protons and electrons.
2. electrons 3. neutrons. 5. protons and neutrons.

30. The temperature at which the vapor pressure of a liquid is the same as the external pressure is the
1. boiling point.
2. melting point. 4. barometric pressure.
3. surface tension. 5. hydration point.

31. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

32. The atomic particles that have an amu of zero are
1. protons.
2. neutrons.
3. electrons.
4. protons and electrons.
5. protons and neutrons.

33. Chloride ion in water solution will be precipitated with a solution of
1. $AgNO_3$
2. NH_4OH
3. HNO_3
4. both 1 and 2.
5. 1, 2 and 3.

34. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

35. An odd number of electrons is found in
1. HCl 2. ClO_2 3. Cl_2O_7 4. Cl_2O 5. HClO

36. Barium reacts with sulfur or oxygen. The two compounds that are formed are
1. an acid and an oxide.
2. an acid anhydride and an oxide.
3. a salt and a basic anhydride.
4. an acid anhydride and a basic anhydride.
5. two salts.

37. The formula for a compound is XY_2. X is 20% of the compound by weight. If the atomic weight of X is 30, then the atomic weight of Y is
1. 60 2. 80 3. 120 4. 160 5. none of these answers.

38. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

39. Pure hydrogen chloride can be prepared from
1. NaCl and H_3PO_4
2. NaCl and H_2O
3. HCl and NH_4Cl
4. NaOH and Cl_2
5. NaCl and NaOH

40. The number of atomic particles that can be exactly determined from the formula, HCl, is the number of
1. protons.
2. electrons.
3. neutrons.
4. protons and electrons.
5. protons, neutrons and electrons.

41. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

42. The non-metallic element that is a liquid at room temperature is
1. Hg 2. Br_2 3. Cl_2 4. F_2 5. I_2

43. Which compound is polar?
1. H_2S 2. CO_2 3. CCl_4 4. H_2 5. N_2

44. 44.8 liters of a gas are collected at $0^{\circ}C$ and 2 atmospheres. How many moles of gas have been collected?

1. $\frac{44.8}{22.2}$ moles
2. $\frac{44.8}{22.4} \times \frac{2}{1}$ moles
3. $\frac{44.8}{22.4} \times \frac{1}{2}$ moles
4. $\frac{22.4}{44.8} \times \frac{2}{1} \times 273$ moles
5. none of these answers

45. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

46. How much heat is needed to change 10 grams of ice at $-10^{\circ}C$ to water vapor at $-10^{\circ}C$?
1. 540 calories
2. 5400 calories
3. 6200 calories
4. 100 calories
5. none of these

47. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

48. HCl is made in the laboratory from
1. NaCl and H_2SO_4.
2. NaCl and H_2O.
3. NaOH and NaOCl.
4. Na_2SO_4 and NaCl.
5. $NaHSO_4$ and NaCl.

49. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

50. Which of the following measurements takes on greater meaning when the atmospheric pressure is known?
1. heat of fusion
2. heat of vaporization
3. boiling point
4. melting point
5. surface tension

51. The metallic bond is strongest in the
1. active metals
2. group II A metals
3. halogens
4. metalloids
5. transition metals

52. The high boiling point of water is due to
1. the ionic bonding in the water molecule.
2. the hydrogen bonding between water molecules.
3. the polar nature of the water molecule.
4. 1 and 3.
5. 2 and 3.

53. Molecular forms of oxygen have the formulas
1. O and O_2.
2. O_2 and O_3.
3. O^{-2} and O_2.
4. O^{-2} and O_3.
5. O^{-2} and O^{-3}.

54. Which of the following statements is <u>not</u> ture about acids that form -ite salts?
    1. They contain hydrogen.
    2. They must contain oxygen.
    3. The acid former is in a lower oxidation state.
    4. The acid ends in -ous.
    5. The acid contains an acid former and one other element.

55. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

56. Phosphoric acid has been partially neutralized if a product of the reaction with sodium hydroxide includes
    1. NaH_2PO_4. 2. Na_2HPO_4. 3. Na_3PO_4. 4. Na_3PO_3.
    5. 1 and 2.

57. The sum of the coefficients of the balanced equation below is

$$CO_2 + NaOH \rightarrow \text{normal salt} + \text{water}$$

    1. 3 2. 3 3. 5 4. 6 5. none of these

58. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

59. Five moles of hydrogen are produced in the reaction of sodium and water. How many grams of water have reacted? (Na = 23)
    1. 18 g. 2. 90 g. 3. 180 g. 4. 230 g. 5. none of these

60. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

61. Magnesium ions have the same number of electrons as each of the following except,
    1. Ca^{+2} 2. O^{-2} 3. F^- 4. Na^+ 5. Ne

62. 10 liters of a gas are collected at $40^\circ C$ and 600 mm. What is the volume of the gas at S.T.P.?
    1. $V_2 = 10 \times \frac{40 \times 600}{760}$
    2. $V_2 = 10 \times \frac{600}{760 \times 20}$
    3. $V_2 = 10 \times \frac{600}{760} \times \frac{273}{313}$
    4. $V_2 = 10 \times \frac{600}{760} \times \frac{313}{273}$
    5. none of the answers given

63. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

64. Which of the following combinations of elements should not be expected to react with each other?
1. Na and F
2. Cl and Br
3. Fr and Ne
4. Si and O
5. Fe and P

65. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

66. Which of the following combinations of atoms contain the greatest number of electrons gained from some other substance.
1. SO_2 2. O_2 3. NH_4^+ 4. H_2O 5. SO_4^{-2}

67. The electron dot symbol for O^{-2} is

1. $[:\ddot{O}:]^{-2}$ 2. $[\ddot{O}:]^{-2}$ 3. $[:\ddot{O}:]$ 4. $[\dot{O}]^{-2}$

5. $[\dot{O}]^{-2}$

69. In a compound of only oxygen and nitrogen, the oxidation number of nitrogen is 3.
1. NO 2. N_2O 3. N_3O 4. N_2O_3 5. N_7O_8

70. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

71. In chemistry a mole is
1. a beauty mark.
2. a small animal.
3. the number of molecules in 44 g. of CO_2.
4. 6.02 billion particles.
5. the number of hydrogen atoms in 18 grams of H_2O.

72. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

73. The multivalence characteristics of transiton metals can best be understood by taking into account unfilled
1. s orbitals.
2. p orbitals.
3. d orbitals.
4. f orbitals.
5. s and p orbitals.

74. The correct formula for calcium sulfite is
1. CaS 2. Ca_2S 3. $CaSO_3$ 4. Ca_2SO_3 5. $CaSO_4$

75. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

76. The electron dot symbol for a chlorine atom is

1. $\dot{Cl}$ 2. $:\ddot{Cl}:$ 3. $:\ddot{Cl}:$ 4. $:\ddot{Cl}:$ 5. $\ddot{Cl}$

77. At one atmosphere external pressure, the vapor pressure of liquid water
1. is 760 mm.
2. depends on the temperature.
3. is 100°C.
4. may be greater than the external pressure.
5. is equal to the heat of vaporization.

78. The best example for a molecule that is covalently bonded is
1. Li_2O 2. NaCl 3. BaO 4. HCl 5. NaH

79. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

80. The most active metallic element is
1. Fe 2. Al 3. Na 4. Li 5. Fr

81. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

82. Lithium and chlorine form a compound with
1. ionic bonding.
2. covalent bonding.
3. coordinate bonding.
4. metallic bonding.
5. hydrogen bonding.

83. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

84. The most abundant element (by weight) in the earth's crust is
1. oxygen.
2. silicon.
3. iron.
4. aluminum.
5. none of these.

85. Which of the following products are formed from the reaction of $An(OH)_2$ and NaOH?
1. water and a salt.
2. a salt.
3. a gas and an oxide.
4. an acid and water.
5. none of the answers given.

86. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

87. What is the reducing agent in the following reaction?
$Al + H_2 \rightarrow AlH_3$
1. hydrogen gas.
2. hydride ion.
3. aluminum ion
4. aluminum metal.
5. aluminum hydride.

88. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

89. According to the kinetic theory, the average kinetic energy of a aolid and a liquid may be compared by measuring
1. the heat of crystalization of the two substances.
2. the temperature of the two substances.
3. the masses of the particles making up the substances.
4. the speeds of the individual particles.
5. the heat in one molecule of each substance.

90. The number of molecules of two gases are the same when the volumes, pressure, and temperatures of the two gases are the same. This is a statement of
1. Boyles law.
2. Charles law.
3. the law of definite proportions.
4. the law of multiple proportions.
5. Avogardro's hypothesis.

91. A substance that gains electrons in a chemical reaction has reacted with
1. an acid.
2. a base.
3. an oxidizing agent.
4. a reducing agent.
5. a catalyst.

92. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

93. How many grams of carbon dioxide are produced from 18 grams of carbon (C = 12)?
1. 12 g. 2. 44 g. 3. 66 g. 4. 88 g. 5. none of these answers

94. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

95. On heating, PbO_2 yields oxygen. How many moles of PbO_2 are necessary to make 64 g. of oxygen? (Pb = 207)
1. 1/2 mole
2. 2 moles
4. 4 moles
4. 478 moles
5. none of these

96. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

97. Se contains 6 electrons in the outer energy level. H_2Se can then be expected to be
1. polar.
2. tetrahedral.
3. ionically bonded.
4. a base in water.
5. linear.

98. FeO does not react with water while BaO does. FeO can be classified as
1. an acid anhydride.
2. a basic anhydride.
3. an oxide.
4. 1 and 3.
5. 2 and 3.

99. An amphoteric substance
1. reacts with acids.
2. reacts with bases.
3. is an oxide.
4. 1 and 2.
5. 1, 2 and 3.

100. Mark the same answer as in the preceding question. 1. 2. 3. 4. 5.

SEAT #_____ CHEMISTRY 115 STUDENT SURVEY

PLEASE NOTE: This is not a test. The purpose of this survey is to gather information that will help improve Chemistry testing. To do this we need your help. Above all, we need honest, thoughtful answers.

This survey will NOT be used in any way for determining your grade in this course.

DIRECTIONS:
1) Read each statement carefully and place the NUMBER of the answer nearest your opinion in the space to the left of the statement.
2) There are NO RIGHT OR WRONG ANSWERS. An answer is right if it is true for you.
3) Be sure to answer every item; do not omit any item.
4. This survey concerns itself only with THEORY QUIZZES, MINIMUM ATTAINMENT TESTS (MAT), and HOUR EXAMS in Chemistry 115.

_____ 1. Material for test questions on the test you took were directly taken from assignments in the textbook.
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 2. Material for test questions on the tests you took were directly taken from the study guides.
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 3. Material for test questions on the tests you took were directly taken from the lectures.
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 4. The test questions on the tests you took required only that you remember some memorized facts.
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 5. Thinking about facts studied was important in answering test questions.
1. almost never. 4. often.
2. a few times. 3. sometimes 5. almost always.

_____ 6. Two or more chemical ideas were needed to answer each test question.
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 7. The test questions on your form were difficult to understand.
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 8. This chemistry course was a challenge to your thinking ability.
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 9. This chemistry course was a challenge to your memorizing ability.
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 10. The tests reflected lecture and assigned material.
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 11. Your test scores reflected your understanding of the chemistry you studied.
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 12. The chemical substances and reactions used in the test question were the same as those studied in preparing for the test.
1. almost never. 4. often.
2. a few times. 3. sometimes. 5. almost always.

_____ 13. In studying for the tests, how much time was spent in memorizing facts?
1. very little time.
2. less than 1/2 time. 4. more than 1/2 time.
3. about 1/2 time. 5. most of the time.

_____ 14. In studying for the tests, how much time was spent in trying to understand ideas and relations of facts to one another?
1. very little time.
2. less than 1/2 time. 4. more than 1/2 time.
3. about 1/2 time. 5. most of the time.

_____ 15. How often did you compare your type of test with the other type of test?
1. never. 4. often.
2. a few times. 3. sometimes. 5. every time.

_____ 16. How did the difficulty of your tests compare with the other form tests? Compared to the other form, my form was
1. much easier.
2. usually easier. 4. much harder.
3. about the same difficulty. 5. no opinion.

APPENDIX D

IDENTIFICATION OF QUESTION TYPE

ON FINAL EXAMINATIONS

EXAMINATION QUESTIONS IDENTIFIED BY TYPE

Pilot Study

Understanding questions		Knowledge questions	
1	47	2	49
3	50	6	53
4	51	8	54
5	52	9	57
7	55	11	59
10	56	12	62
13	61	14	72
18	64	15	73
19	66	17	75
20	67	22	77
21	68	23	78
27	70	24	80
29	71	25	82
34	76	26	88
35	83	30	89
36	85	31	91
39	87	32	93
41	95	33	99
43	97	38	100
44	98	42	
45			

Principal Study

Understanding questions		Knowledge questions	
1	50	6	48
3	51	9	53
4	52	11	54
7	56	12	57
14	61	13	67
21	64	15	73
22	66	18	74
23	69	20	76
24	71	25	77
27	85	26	80
35	87	29	82
36	89	30	84
37	93	32	90
40	95	33	91
43	97	39	99
44	98	42	
46			

APPENDIX E

THE EDUCATIONAL SET SCALE

EDUCATIONAL SET SCALE

Laurence Siegel and LIla C. Siegel

Miami University

We have selected several courses in which large numbers of students tend to enroll. For each course we have listed a variety of topics covered, items of information presented, and tasks to be accomplished.

Assume that you are enrolled in these courses and therefore are required to learn about each of the topics listed on the following pages.

The topics are listed in groups of three. Decide which one of the three topics in each group would interest you most and which one would interest you least. Rank the topics in each set of three indicating the extent to which each one interests you by assigning

1. to the topic that interests you MOST
2. to the topic in which you have intermediate interest
3. to the topic that interests you LEAST

You may not omit a rank for any topic or assign the same rank to two topics within a set. Although it may sometimes be difficult for you to make a decision, it is imperative that you do so by assigning ranks of 1, 2, and 3 to the topics listed in each set.

(2)

Examples:

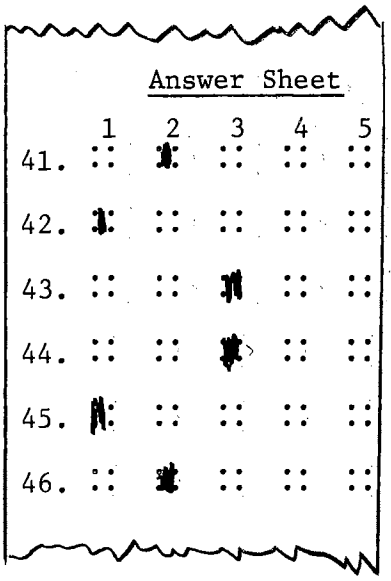
Assume you are enrolled in a GEOGRAPHY course and must learn about the following:

A. Items 41 - 43

41. The causes of earthquakes.
42. The names of the world's major oceans.
43. The distinction between anthracite and bituminous coal.

B. Items 44 - 46

44. The length of the Panama Canal.
45. The influence of terrain upon farming procedures.
46. The location of major United States timber resources.



This person has marked his answer sheet for two sets of topics. He has indicated that, of the three topics in Set A, he is most interested in 42 ("names of the world's oceans"); least interested in 43 ("distinction between anthracite and bituminous coal"); and has an intermediate interest in 41 ("causes of earthquakes"). Of the three topics in Set B, he is most interested in 45, least interested in 44, and has intermediate interest in 46.

Note: Although the answer sheet has 5 answer positions, you are to use only positions 1, 2, and 3 to rank the three topics in each set.

Remember also that you must rank every topic on the set and you cannot assign the same rank to any two topics.

(3)

KEY:

1 - MOST interest in this topic
2 - Intermediate interest in this topic
3 - LEAST interest in this topic

****

Assume you are enrolled in a BUSINESS & ECONOMICS course and must learn about the following:

A. Items 1 - 3

1. The functions of the Securities and Exchange Commissioner.
2. Factors operating to diminish the size of the U. S. gold reserve.
3. Why an "easy money" policy may be unsound public policy.

B. Items 4 - 6

4. The names of the components of the "Gross National Product."
5. The meaning of an "odd lot" in stock purchases.
6. The purpose underlying agricultural price supports.

C. Items 7 - 9

7. Major events in the growth of the U. S. labor unions.
8. The names of the nations constituting the "common market."
9. Factors underlying a decision to invest vs. a decision to save.

D. Items 10 - 12

10. The name of an inflationary potential in the economy which is artificially kept from registering itself in prices.
11. The relationship between disposable incomes and total expenditures for consumer goods.
12. The ways in which Federal Reserve monetary policy attempts to accomplish its goals.

E. Items 13 - 15

13. How to read entries in the stock market page of a newspaper.
14. The present established worth of an ounce of gold.
15. What is meant by a "holding company."

(Go Right On To The Next Page)

(4)

KEY:

1 - MOST interest in this topic
2 - Intermediate interest in this topic
3 - LEAST interest in this topic

****

Assume you are enrolled in a SOCIAL SCIEMCE course and must learn about the following:

A. Items 16 - 18

16. Environment as a partial determinant of mental illness.
17. The relationship between I.Q. and scholastic success in a college or university.
18. Average ages at which children first begin to creep, walk, identify colors, etc.

B. Items 19 - 21

19. The difference between a psychiatrist, a psychologist, and a psychoanalyst.
20. The percentage of youngsters apprehended as juvenile delinquents who subsequently are apprehended by the law for committing a major crime.
21. The role of psychological testing in vocational guidance.

C. Items 22 - 24

22. The proportion of United States residents now over age 65.
23. The effects of caffeine upon muscular coordination.
24. The meaning of "percentile" in interpreting test results.

D. Items 25 - 27

25. The primary symptoms differentiating psychotic (insane) behavior from neurotic behavior.
26. The specific human capabilities known to deteriorate after about age 60.
27. The average incomes of various classifications of workers in the U.S. (e.g., unskilled, semiskilled, technical, professional, etc.)

E. Items 28 - 30

28. The percentage of family income that ought to be budgeted for rent, food, clothing, recreation, etc.
29. What it is that the psychoanalyst attempts to do.
30. The current divorce rate in the United States.

---

(5)

KEY:

1 - MOST interest in this topic
2 - Intermediate interest in this topic
3 - LEAST interest in this topic

****

Assume you are enrolled in a NATURAL SCIENCE course and must learn about the following:

A. Items 31 - 33

31. The explanation for the fact that it is sometimes difficult to recognize voices on the telephone.
32. The distance from earth to the other planets in our galaxy.
33. The critical velocity required to escape the earth's gravitational pull.

B. Items 34 - 36

34. The names of the elements included within the "halide" group.
35. Statement of Newton's third law of motion.
36. The significance of a pH of 6.

C. Items 37 - 39

37. Formula for converting centrigrade temperature readings to fahrenheit readings.
38. The difference in chemical structure between H_2O (water) and H_2O_2 (hydrogen peroxide).
39. The distinction between "anode" and "cathode".

D. Items 40 - 42

40. Chemical factors associated with transmitting neural impulses.
41. Why thrust is generated by a jet engine.
42. The chemical structure of penicillin.

E. Items 43 - 45

43. The relative conductivity of certain substances (e.g., iron, copper, zinc, wood).
44. The meaning of "specific gravity."
45. The effect of increased pressure upon the boiling point of a liquid.)

APPENDIX F

RAW SCORES AND SURVEY RESPONSES

PILOT STUDY

FRACTION ANSWERING EACH QUESTION CORRECTLY ON FINAL EXAMINATION

Understanding Subtest		Knowledge Subtest	
Question	Answering Correctly	Question	Answering Correctly
1	.302	2	.787
3	.757	6	.647
4	.416	8	.235
5	.132	9	.735
7	.787	11	.419
10	.257	12	.912
13	.368	14	.654
18	.066	15	.213
19	.338	17	.522
20	.390	22	.632
21	.118	23	.507
27	.338	24	.346
29	.184	25	.728
34	.272	26	.767
35	.595	30	.368
36	.287	31	.831
39	.059	32	.456
41	.360	33	.118
43	.221	38	.074
44	.507	42	.516
45	.132	49	.706
47	.140	53	.154
50	.640	54	.559
51	.206	57	.243
52	.177	59	.191
55	.331	62	.574
56	.309	72	.515
61	.309	73	.368
64	.456	75	.721
66	.515	77	.471
67	.360	78	.463
68	.713	80	.552
70	.397	82	.478
71	.147	88	.765
76	.331	89	.735
83	.265	91	.596
85	.559	93	.890
87	.250	99	.757
95	.176	100	.221
97	.265		
98	.559		

PILOT STUDY

FINAL EXAMINATION RAW SCORES

Knowledge Group			Understanding Group		
Student Number	K*	U**	Student Number	K*	U**
2	27	10	1	27	19
3	11	8	4	9	6
6	9	10	5	27	28
8	25	17	7	10	10
10	23	7	9	13	8
13	23	10	11	32	21
14	15	11	12	24	23
16	26	13	15	18	13
18	9	5	17	16	14
19	18	14	20	30	21
21	28	14	22	30	19
24	21	12	23	16	11
28	31	13	25	20	12
31	23	15	26	22	17
33	23	17	27	23	17
34	14	3	29	28	23
35	32	21	30	19	11
37	18	20	32	26	23
39	27	9	36	20	11
42	28	15	38	22	17
44	28	15	40	24	14
46	23	13	41	27	23
49	7	5	43	21	14
50	19	7	45	24	11
52	13	14	47	21	17
54	16	11	48	20	16
59	17	9	51	15	11
60	27	20	53	22	18
62	19	10	55	32	27
65	23	14	56	19	13
67	20	11	57	18	12
69	17	11	58	14	15
72	21	8	61	25	19
74	17	17	63	15	10
76	14	9	64	27	21
77	21	9	66	20	16
79	13	1	68	27	20
83	25	14	70	31	26
84	24	21	71	32	18
90	28	18	73	27	23
91	20	8	75	7	10
93	18	6	78	19	15
97	17	9	80	14	10

K* Knowledge questions
U** Understanding questions

Knowledge Group		
Student Number	K*	U**
98	29	22
101	17	9
102	19	10
103	14	9
105	8	11
106	12	5
109	24	8
110	24	14
112	17	5
115	30	17
117	14	7
119	28	19
121	19	9
124	20	8
125	21	9
126	19	9
127	19	7
128	23	16
136	27	17

Understanding Group		
Student Number	K*	U**
81	14	10
82	17	15
85	21	16
86	25	14
87	23	19
88	16	8
89	24	16
92	4	9
94	17	13
95	27	16
96	13	10
99	20	11
100	20	9
104	21	15
107	17	14
108	26	18
111	19	8
113	33	29
114	21	12
116	22	19
118	20	12
120	26	19
122	19	13
123	17	9
129	18	16
130	22	12
131	19	16
132	12	12
133	11	14
134	29	19
135	33	26

PILOT STUDY

RESPONSES TO STUDENT SURVEY

Question	Group	Response Number 1	2	3	4	5	Chi-square
1	Knowledge	1	5	10	18	22	
	Understanding	3	6	16	20	14	3.79
2	Knowledge	1	7	19	25	4	
	Understanding	3	11	16	15	9	9.09
3	Knowledge	1	6	13	28	8	
	Understanding	1	9	23	23	3	5.99
4	Knowledge	2	6	14	13	21	
	Understanding	3	4	18	16	18	1.03
5	Knowledge	0	5	6	19	26	
	Understanding	0	3	7	25	24	1.39
6	Knowledge	7	16	21	9	3	
	Understanding	12	20	21	5	1	3.68
7	Knowledge	1	7	23	19	6	
	Understanding	1	5	13	21	19	9.84
8	Knowledge	0	0	7	16	33	
	Understanding	0	1	4	13	41	1.43
9	Knowledge	9	13	12	11	11	
	Understanding	15	11	17	11	5	7.87
10	Knowledge	12	21	11	7	5	
	Understanding	14	22	17	5	1	4.39
11	Knowledge	1	1	6	18	30	
	Understanding	0	4	7	19	29	0.44
12	Knowledge	5	9	21	15	6	
	Understanding	6	13	20	13	7	0.98
13	Knowledge	0	1	6	26	23	
	Understanding	0	3	13	27	16	4.72
14	Knowledge	2	5	15	20	14	
	Understanding	3	4	19	24	9	1.85
15	Knowledge	6	11	7	18	14	
	Understanding	12	12	10	13	12	3.46
16	Knowledge	9	7	26	11	3	
	Understanding	6	8	26	14	5	1.12

Question	Group	1	2	3	4	5	Chi-square
17	Knowledge	8	20	14	11	3	
	Understanding	14	16	12	12	5	2.70
18	Knowledge	1	6	17	17	15	
	Understanding	2	11	21	9	16	3.51
19	Knowledge	0	12	22	14	8	
	Understanding	0	0	9	41	9	27.78

PRINCIPAL STUDY

FRACTION ANSWERING EACH QUESTION CORRECTLY ON FINAL EXAMINATION

Understanding Subtest		Knowledge Subtest	
Question	Fraction Answering Correctly	Question	Fraction Answering Correctly
1	.283	6	.737
3	.742	9	.439
4	.222	11	.338
7	.813	12	.242
14	.434	13	.904
21	.318	15	.535
22	.758	18	.520
23	.556	20	.546
24	.379	25	.788
27	.328	26	.818
35	.424	29	.485
36	.535	30	.848
37	.394	32	.343
40	.323	33	.419
43	.419	39	.348
44	.364	42	.289
46	.288	48	.712
50	.732	53	.732
51	.273	54	.293
52	.470	57	.384
56	.242	67	.377
61	.202	73	.667
64	.546	74	.652
66	.454	76	.778
69	.818	77	.424
71	.576	80	.283
85	.242	82	.646
87	.399	84	.561
89	.258	90	.626
93	.556	91	.596
95	.227	99	.742
97	.268	99	.742
98	.601		

PRINCIPAL STUDY

FINAL EXAMINATION - EDUCATIONAL SET SCALE RAW SCORES

Knowledge Group

Student Number	K*	U**	ESS***	Student Number	K	U	ESS
1	16	13	2	73	22	11	9
2	24	18	7	76	22	15	1
4	5	7	11	78	21	15	10
5	11	11		80	16	8	5
8	17	18	10	82	12	5	
11	22	16	8	83	23	18	11
14	17	17		85	13	10	9
15	15	19	1	87	13	10	5
17	15	12	-1	88	28	24	
19	19	20		89	13	10	
20	13	12		90	24	15	16
22	23	18		92	18	11	8
23	16	12	10	94	17	19	15
26	7	7	-2	97	25	24	4
27	17	15	0	100	13	6	11
28	27	20	9	102	12	12	
29	26	19	8	104	14	12	10
30	20	10	17	105	21	16	0
33	24	22	16	106	14	11	
34	20	17		110	19	15	
37	17	21	3	112	21	10	
38	17	10	3	115	14	9	
40	24	22	15	116	9	12	
42	21	13	10	118	21	15	14
44	25	25	10	121	11	12	
45	19	15	8	122	14	7	8
49	10	13	12	123	25	23	13
51	24	21		126	11	8	2
52	9	12		129	15	13	13
54	21	17	17	131	25	12	6
55	18	21	12	132	9	9	9
57	16	9	8	133	26	18	7
59	21	20		135	17	13	
61	17	19	3	137	4	6	
63	26	17	-3	139	10	10	
64	18	9	6	141	11	6	
65	14	17	-6	143	17	17	
67	22	20	1	146	17	16	
70	21	19	14	148	20	20	
72	16	21	11	150	23	19	23

K* Knowledge questions.
U** Understanding questions
ESS*** Unadjusted Educational Set Scale Score.

Knowledge Group (Continued)

Student Number	K*	U**	ESS***
153	22	22	3
154	20	17	8
155	12	9	-1
158	17	11	16
160	29	29	23
161	20	15	-9
163	26	24	-1
164	13	14	-1
165	6	7	
167	13	8	5
169	20	13	-2
171	21	18	
173	11	14	
176	10	11	13
178	13	11	2
180	18	18	2
181	22	14	8
182	13	14	2
183	14	16	
184	20	16	12
187	23	19	7
189	17	13	
190	16	10	4
191	18	18	
193	8	7	7
194	19	19	9
196	24	22	11
197	15	12	

PRINCIPAL STUDY

FINAL EXAMINAGION - EDUCATIONAL SET SCALE RAW SCORES

Understanding Group

Student Number	Subtest K	Subtest U	ESS	Student Number	Subtest K	Subtest U	ESS
3	11	12	3	96	11	6	
3	13	21	9	98	20	16	
7	6	8		99	19	13	7
9	21	23		101	21	18	2
10	6	11		103	8	7	
12	12	13	12	107	16	14	
13	23	17		108	18	7	-5
16	25	27	15	109	18	10	1
18	17	15		111	13	11	13
21	20	13	10	113	26	19	7
24	11	3		114	27	25	15
25	25	19	8	117	20	18	9
30	10	11	5	119	11	13	
32	5	11	10	120	26	25	11
35	26	25	6	124	14	15	15
36	15	8	11	125	10	6	16
39	18	25	10	127	7	6	-2
41	9	10		128	20	19	17
43	22	20	9	130	17	12	9
46	24	19		134	17	7	-1
47	23	22	14	136	27	23	9
48	15	12		138	9	13	2
50	20	14	10	140	26	18	18
53	15	14	7	142	24	25	13
56	17	18		144	14	7	
58	12	12		145	16	14	
60	17	14	-1	147	9	7	-4
62	21	14	16	149	26	17	4
66	20	22	7	151	13	15	
68	16	15	6	152	20	13	
69	16	20	4	156	14	12	-5
71	19	11	2	157	13	11	1
74	24	27		159	11	9	
75	18	11	7	162	22	16	4
77	29	30	23	166	22	17	13
79	26	24	5	168	25	16	5
81	16	10		170	15	12	13
84	19	7		172	11	11	
86	11	12	9	174	26	24	13
91	19	10		175	26	22	9
93	13	14	-3	177	18	11	6
95	15	11	15	179	8	6	

Understanding Group (Continued)

Student Number	K	U	ESS
185	19	12	
186	26	27	-1
188	17	11	6
192	8	6	-2
195	9	5	
198	25	23	23

PRINCIPAL STUDY

RESPONSES TO STUDENT SURVEY

Question	Group	Response Number 1	2	3	4	5	Chi-square
1	Knowledge	2	1	21	31	28	
	Understanding	7	7	18	27	16	10.52
2	Knowledge	3	6	19	34	21	
	Understanding	3	6	24	27	15	1.99
3	Knowledge	1	4	28	30	20	
	Understanding	0	5	32	27	11	2.64
4	Knowledge	7	22	32	13	9	
	Understanding	18	26	23	4	4	12.80
5	Knowledge	0	1	12	32	38	
	Understanding	0	1	4	20	50	7.57
6	Knowledge	0	10	32	34	7	
	Understanding	3	7	24	28	13	3.13
7	Knowledge	22	24	24	12	1	
	Understanding	5	12	31	19	8	22.28
8	Knowledge	3	6	14	26	34	
	Understanding	1	2	7	24	41	5.69
9	Knowledge	1	9	23	30	20	
	Understanding	8	13	23	31	10	10.73
10	Knowledge	0	1	9	28	45	
	Understanding	0	2	14	22	37	2.49
11	Knowledge	0	12	27	24	20	
	Understanding	6	8	19	22	20	1.23
12	Knowledge	3	11	30	30	9	
	Understanding	6	12	36	16	5	6.62
13	Knowledge	3	19	38	18	5	
	Understanding	11	23	23	10	8	11.28
14	Knowledge	4	15	32	17	15	
	Understanding	2	12	20	23	18	4.30
15	Knowledge	11	25	14	15	18	
	Understanding	6	23	16	19	11	3.45
16	Knowledge	7	47	14	3	12	
	Understanding	0	0	5	61	9	107.22

VITA

Eugene Charles Brott

Candidate for the Degree of

Doctor of Education

Thesis: A STUDY OF THE EFFECT OF SELECTED MULTIPLE-CHOICE ITEMS ON CONCEPTUAL AND FACTUAL ORIENTATION OF STUDENTS IN GENERAL CHEMISTRY

Major Field: Higher Education

Biographical:

Personal Data: Born in North Judson, Indiana, November 5, 1933, the son of Victor H. and Frieda Brott.

Education: Graduated from Edwin Denby High School, Detroit, Michigan, 1951; received the Bachelor of Science Degree in Education from Concordia Teachers College, River Forest, Illinois, in June, 1955. Attended summer Chemistry Institutes at St. Louis University from 1958-1960. Received the Master of Arts degree in Science Education from Washington University, St. Louis, Missouri in 1962. Completed requirements for the Doctor of Education degree in May, 1969.