RELATIONSHIPS BETWEEN FRESHMAN TEST SCORES AND GRADES IN FIRST SEMESTER GENERAL CHEMISTRY

By

ELBERT LLOYD GRIFFIN

Bachelor of Arts
Stephen F. Austin State College
Nacogdoches, Texas
1928

Master of Arts
University of Texas
Austin, Texas
1947

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RELATIONSHIPS BETWEEN FRESHMAN TEST SCORES

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Thesis Approved:

J. Sorensen
Thesis Adviser

Henry P. Johnston

William W. Rambo

Howard W. Helding

Robert MacVicar
Dean of the Graduate School

PREFACE

Many studies have been reported in the literature concerning possible correlation between educational aptitude, as revealed by achievement tests, and success in college as measured by the student's average grade, grade-point average, or honors-point ratio. There has been much less written, however, concerning the prediction of success in a particular subject.

The prediction of probable success in the first semester of freshman chemistry is particularly important in the case of the student who has had no previous instruction in the subject, for, if a large majority of these fail, and many do, repeatedly, a considerable imbalance in the use of laboratory facilities and the scheduling of teaching loads between the first and second semesters is only one result that affects adversely our program of higher education. There is not much doubt that failure in college not only is an unpleasant event but that it also has a certain adverse effect on the college or university involved. In addition, the ones who fail have been a retarding influence on the more limited group who can profit from the course.

Indebtedness is acknowledged to Dr. Henry P. Johnston, who suggested the study; to Drs. Howard W. Heding and Helmer E. Sorenson for guidance in the early phases of the study, to Dr. William W. Rambo, for his valuable counseling in the statistical computations; and to Dr. John W. Hamblen and his staff at the Computing Center.

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CHAPTER I

THE PROBLEM

Introduction

Many studies have been made to determine the correlation between educational aptitude, as revealed by achievement tests, and success in college as measured by the student's average grade, grade point average, or honors point ratio. These correlations generally range between 0.40 and 0.50, although considerably lower or higher coefficients have been reported at various times.[1] There has been much less written, however, concerning the prediction of success in a particular subject.

Statement of the Problem

In regard to students of freshman classification who have had no previous instruction in chemistry, what is the relationship between their previous scholastic attainment, as indicated by their scores made on (1) the psychological examination, (2) the language usage test, and (3) the mathematics aptitude test, given them at the time of enrollment, and the marks they make upon completing the first semester of college chemistry (Chemistry 114) at Oklahoma State University?

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[1] Albert B. Crawford and Paul S. Burnham, Forecasting College Achievement (New Haven, 1946), p. 89.

Definitions and Interpretations

<u>Relationships</u> refer to coefficients of correlation, calculated by means of the Pearson Product Moment Method, between the variables involved.

<u>Scores</u> refer to the net numerical score obtained on each test.

<u>The three tests</u> referred to are those most entering freshmen at Oklahoma State University are required to take prior to matriculation.

<u>Marks</u> refer to the numerical grade assigned each student by the chemistry instructors upon completion of the course.

<u>Those who had no previous instruction in chemistry</u> refers to those whose record shows no evidence of their having attended any chemistry classes up to the time of enrollment in college chemistry at Oklahoma State University.

<u>The first semester of beginning college chemistry</u> refers to Chemistry 114 at Oklahoma State University.

The Hypothesis

The score made on the American Council on Education Psychological Examination, or the Cooperative School and College Ability Test, together with the scores made in the examinations appraising achievement in English and algebra, significantly estimates the incoming chemistry student's success, as judged by marks received upon completion of the course in the first semester of beginning college chemistry at Oklahoma State University.

Purposes of the Study

The purposes of the study are: (1) to provide evidence of the relationship of the factors mentioned in the hypothesis to academic success in the first semester of beginning college chemistry; and (2) to report this evidence in such a manner that it might prove helpful to high school, college, and university teachers who counsel students.

The Assumptions

Different mental processes are required for different subject-matter fields and individuals differ within themselves as well as among others in using the mental processes they possess. Thus educational growth may be fostered by adequate educational guidance.

Growing demand for higher education makes the problem of adequate educational guidance more pressing than ever.

The purpose of the American Council on Education Psychological Examination or the Cooperative School and College Ability Test is to appraise what has been called scholastic aptitude or general intelligence, with special reference to the requirements of most college curricula. The scores made on either of these tests are indicative of the mental alertness of the students and reflect their previous education. However, as a measure of capacity for learning, they are more reliable when used in combination with other evidences of ability.

Success in every college course is dependent upon certain minimum language abilities, but for satisfactory achievement in technical and scientific courses certain fundamental mathematical reasoning powers and skills are required in addition. Therefore, indices in these two areas will be the logical complement to the index furnished by the

Psychological Examination or the Ability Test.

The facilities, teaching personnel, and coordination of instruction in Chemistry 114 has been consistent enough during the period investigated to warrant acceptance of these factors as constants.

Need for the Study

At Oklahoma State University, as at most colleges and universities, training is given in a variety of fields. A student's success in any field is dependent upon abilities acquired in previous training. If dependable methods of assaying this background are employed, it should be possible, not only to make an over-all prediction of the degree of success a student is likely to attain in his whole college program, but also to determine the probable accomplishment that is likely in specific areas of learning. In the area of chemistry, for example, the prognosis would have value whether the student is to attempt a major in chemistry or is to take a limited number of courses in this field in order to proceed with other studies. If the probable outcome is very doubtful or unfavorable, remedial work would be all but mandatory, or other areas not requiring this science could be sought.

Although there has been widespread belief that scores in certain tests would be an aid in determining an individual's fitness for particular courses or fields of concentration, insufficient evidence is available on which to make satisfactory predictions. In many cases the only clues to the application of test results that have been accessible in counseling have been (1) the mere knowledge of the area and the content of the tests given, which has the resultant flaw of yielding highly subjective judgments, and (2) information from investigations made at other institutions on the predictive value of certain tests that have been used at those schools, and these are scant in number. The latter situation is partially an individual one in each college and university, and the results obtained at one place may not necessarily be directly comparable with results that would be obtained at another institution. On the other hand, the findings at Oklahoma State University, in the sense that they may indicate trends, could be of value to other interested groups.

Scope and Limitations of the Study

The scope of this study is limited to the relationships stated in the hypothesis as they are manifested for students who have matriculated from a secondary school in the continental United States. Further, these students, having had no previous instruction in chemistry, have enrolled in and received a grade in Chemistry 114 during one of the fall semesters involved in the study, and at the time of enrollment were classified as freshmen.

CHAPTER II

REVIEW OF THE LITERATURE

Historical Background

For many years certain educators have felt the need for an instrument or instruments capable of predicting the probable success of a student after college entry. A great deal of work has been done, therefore, in attempting to find interrelationships between a student's scholastic background in the secondary school and his record of achievement in college. However, numerous problems have arisen to plague the investigators. Some of these have been (1) how can achievement be measured, (2) how can one compensate for variations in the marking systems between schools or between individual teachers in the same school, and (3) how can personal factors--ambition, persistence, and similar qualities--be considered?

Before inquiring into ways and means of improving prediction techniques, it would seem advisable to first investigate the assumption that it was important to predict academic success. Travers thinks the prediction of academic success is of importance in two main situations. First, when an education program is of such a specialized nature that only a limited group can profit by it, predictions of the probable success of those who wish to take the program are important. Second, the prediction of academic achievement is important in the guidance of the individual student, regardless of the nature of the program being pursued, for discrepancies between predicted achievement and actual achievement are often significant symptoms of maladjustment.[1]

From an administrative standpoint there would be two advantages if most who would have failed could have been steered into other channels. The first advantage was stated by Hovey and Krohn who emphasized the gain derived from balancing the teaching load and releasing laboratory facilities from seasonal stresses. They said,

> Being a municipal institution, the University of Toledo has been experiencing a problem common to all public colleges and universities--namely, that recent years have increased the quantity but not the quality of our students. Chemistry departments of such universities have been disturbed by the large number of failures and withdrawals in the first semester of general chemistry, which results in considerable imbalance in the use of laboratory facilities and the scheduling of teaching loads between the first and second semesters.[2]

What was needed, they felt, was a method by which they might predict those students who would be likely to fail chemistry, so that they could be excluded from the course.

The second advantage, also one of efficiency, was voiced by Martin, who attempted to justify the exclusion of certain students from chemistry, at least temporarily, when he said,

> From the administrator's standpoint it is more efficient to use the time of the chemistry teachers to teach chemistry to the students capable of profiting by it, and to assign students who need help in mathematics or English to teachers trained in teaching these subjects.[3]

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[1]Robert M. W. Travers, "Prediction of Success," Measurement of Student Adjustment, eds. Wilma T. Donahue, Clyde H. Coombs, and Robert M. W. Travers (Ann Arbor, 1949), p. 147.

[2]Nelson W. Hovey and Albertine Krohn, "Predicting Failures in General Chemistry," J. Chem. Ed., 35 (1958), 507-9.

[3]F. D. Martin, "A Diagnostic and Remedial Study of Failures in Freshmen Chemistry," J. Chem. Ed., 19 (1942), 274-7.

It has long been assumed that a high percentage of failures is to be expected as a necessary concomitant of college work. Students who could meet minimum entrance requirements have been accepted and have been dealt with collectively without too much regard to individual differences. These conditions still prevail in the average college and university. Failure in college is an unpleasant event for a student as well as for his family and the secondary school from which he graduated. It also has certain adverse effects on the college or university involved. According to conclusions reached by Hazel and Oberly, this is most likely to be the case where admission is based on standards such as are provided by secondary school records rather than scores on an adequate entrance examination. They hold that,

> When a student is admitted to a course it is implied that he has the necessary qualifications to pass it. This view is taken, more often than not, by student, parent, and preparatory school. Failures will occur and mistakes are certain to be made. It is not too much to expect that these be kept at a minimum, however. In order to approach this goal practical predictors of success must be found and then applied as an admission requirement.[4]

It is true, they affirm, that on admission to college a student enters a new educational environment, and much of his success depends on whether he can adjust himself to it. If he is mature enough to have self-discipline and good work habits, he has a fair part of the ingredients of success, because the only other critical requirement is good ability, and this should be assured by the admission criteria.

Two very vital questions evolve out of these preliminary considerations. The first concerns the basis on which the predictions are to be made while the second has legal aspects, for it involves the

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[4]Fred Hazel and H. Sherman Oberly, "Selection and Performance of Students," J. Chem. Ed., 27 (1950), 27-31.

extremely complex problem of denial of admission when the prognosis is poor. This latter question, as of this moment, is a topic of critical concern to admission officers who have stated,

> A few of the state colleges, required by law to admit all graduates of accredited high schools within the state, admit students in the lower fourth of their graduating class on a probational basis. This practice may result in the admission to college of more potential failures and may also create psychological and social problems for the students so admitted. It would appear more reasonable, and surely more charitable, to admit to college students of low high school achievement only on the basis of supporting evidence indicating that academic success is at least a possibility.[5]

In seeking a partial answer to the first question--the basis on which predictions are to be made--there is ample evidence in the general field of forecasting college achievement that many studies have been made to determine the correlation between educational aptitude, as revealed either by achievement tests, high school records, or a combination of both, and success in college, as measured by the student's average grade, grade-point average, or honors-point ratio. These correlations range on the average between 0.40 and 0.50, which is presumed to denote a reasonable, and probably significant, relationship. Many lower, but fewer higher correlations, have been reported at various times.[6] There has been much less written, however, concerning the prediction of success in a particular subject.

Investigations Prior to 1940

The early studies were mainly concerned with the prediction of over-all success in a liberal arts program. In some cases the criterion

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[5] Vivian R. Boughter, John E. Warner, and Emil A. Holtz, "Probation, Suspension, and Related Problems," The N.C.A. Quarterly, 31 (1957), 249-55.

[6] A. B. Crawford, and P. S. Burnham, Forecasting College Achievement

of success was the completion of a four-year program; in others, it was the average grade over a period of one or two semesters. The current trend is to use average first-semester grades or first-year grades, since grades in successive years of college tend to be highly intercorrelated.

One of the first studies designed to make predictions of probable success in a specific field, that of chemistry, was made at Oklahoma Agricultural and Mechanical College (now Oklahoma State University) by Dr. Otto M. Smith and H. M. Trimble in the fall semester of 1928. They summarized their findings thus:

> In conclusion one may repeat the statement that it seems to be possible to predict the performance of the best and of the poorest students. Likewise, it would seem possible, then, to do much with the students through separating them from the others. It also appears doubtful whether any sectioning of the students of the second and third quarters would be profitable.[7]

A more comprehensive study was made at the University of Pennsylvania over a six-year period, beginning in 1930. An aptitude test was administered to all beginning chemistry students. The test in its early form was a test of verbal ability only. It consisted of antonyms, double definitions, and paragraph reading. In 1930, the year of first use for the prediction of probable success in chemistry, a mathematics section of 100 items of increasing hardness from arithmetic, algebra, and geometry were added. Its avowed purpose, according to Dickter, was,

> As an aid in guidance and teaching in college; for example selecting students for admission to the various fields of study, guiding them in their choice of majors, forestalling through supervision the possible failures of doubtful

[7]Otto M. Smith and H. M. Trimble, "Prediction of Future Student Performance," J. Chem. Ed., 6 (1929), 93-97.

> students, and sectioning groups for instructional purposes.[8]

Dickter's study, covering 2604 cases for both semesters of beginning chemistry for the six-year period, showed that there was a significant relation between success in the course and (1) the ability to perform fundamental arithmetical operations, and (2) the ability to read appropriate material. His final conclusion, though, was,

> The situation is an individual one in each university, so the results obtained at one university (Pennsylvania) are not necessarily directly comparable with similar results obtained at other universities.[9]

His findings were important in that they indicated a new trend in investigations of this sort.

A majority of the investigations prior to 1940 were mainly concerned with reaching valid conclusions concerning the optimum pattern of entrance credits from high schools for those wishing to pursue the study of chemistry in college or university. Most reached the conclusion that good high school grades were better than good placement examination scores for picking successful students. Scofield, in 1930, concluded that good high school mathematics grades, especially when combined with good high school chemistry grades, was a superior predictor when compared with placement examination grades.[10] Three other independent investigators,

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[8]M. Richard Dickter, "The Relation Between the Scores on the Scholastic Aptitude Test and College Marks in Chemistry," J. Exper. Educ., 6 (1937), 40-45.

[9]Ibid., p. 40.

[10]M. B. Scofield, "Further Studies on Sectioning in General Chemistry,"

Hermann,[11] in 1931, Steiner,[12] in 1932, and Clark,[13] in 1938, showed that, in general, high school chemistry is advantageous to students who enroll in beginning college chemistry. West, in 1932, reached a dissenting conclusion and surmised that factors such as intelligence are more important than specific high school training.[14]

Further studies during the period 1932-1937, according to Harris, were also concerned with the validity of the high school transcript, rather than an examination administered at matriculation, as a predictor of proficiency in the study of chemistry. A summary of the findings in the six studies relating to achievement in college chemistry reported by him follows:

> 350 students who had high school chemistry showed an initial superiority in college chemistry which later disappeared.
>
> Of 2026 students, those that had studied high school chemistry made college chemistry grades 12 per cent higher and the ones with a high school background of both chemistry and physics made grades 24.5 per cent higher in this subject, than those who had received no previous instruction in either chemistry or physics.
>
> In a group of 3268, composed of some students with no training in high school chemistry, of others with training including this science, and still others with chemistry and physics both, the college chemistry grades of the students having had high school chemistry were no better, and the

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[11] G. A. Hermann, "An Analysis of Freshman College Chemistry Grades with Respect to Previous Study of Chemistry," J. Chem. Ed., 8 (1931), 1376-85.

[12] L. E. Steiner, "Contribution of High School Chemistry Toward Success in the College Chemistry Course," J. Chem. Ed., 9 (1932), 530-37.

[13] P. E. Clark, "The Effect of High School Chemistry on Achievement in Beginning College Chemistry," J. Chem. Ed., 15 (1938), 285-89.

[14] G. A. West, "What Factors Determine Student Achievement in First-Year College Chemistry," Sch. Sci. & Math., 32 (1932), 911-13.

> grades of those with the two sciences were only 2.5 per cent better than the grades of the students who had studied neither of the sciences.
>
> 1034 students without previous chemistry training, when administered a chemistry aptitude test, made grades in college chemistry that correlated significantly (*r*, 0.55) with scores on the test.
>
> Scores made by 183 students with previous chemistry, when administered the Iowa Chemistry Placement Test, showed a correlation coefficient of 0.59 with grades made in college chemistry.
>
> 180 students with previous chemistry were given the same test as above and, in addition, were given the Ohio Psychological Examination. A correlation coefficient of 0.57 was reported for the chemistry test score versus the college chemistry grade, but the psychological test score gave a correlation coefficient of only 0.42 against the same criterion. The multiple correlation coefficient was 0.57 when all factors were combined.[15]

After summarizing several other rather extensive studies concerning the essential factors in student achievement in chemistry, Harris was led to the following conclusion of his own:

> It is the writer's personal opinion, unsupported by anything resembling a regression equation, and based merely on his own findings, total immersion in the results and opinions of other investigators, and some cogitation, that the essential factors in student achievement are, in the order of thier importance: ability (or intelligence or scholastic aptitude, etc.); effort (or drive or degree of motivation); and circumstances (personal, social, economic, and academic).[16]

Studies Since 1940

In diagnosing the most frequent causes of failure in freshman chemistry at Purdue University, F. D. Martin, in 1942, reported that nearly

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[15] Daniel Harris, "Factors Affecting College Grades: A Review of the Literature, 1930-1937," <u>Psychol</u>. <u>Bull</u>., 37 (1940), 125-66.

[16] Ibid., p. 166.

three-fourths of the students who failed chemistry the first time also failed in either English or mathematics, or both. He is firmly convinced that those who have trouble in chemistry are generally poor in reading, writing, and arithmetic.[17] At Purdue no distinction is made now in sectioning those with and those without high school chemistry, for after several years' trial of assigning different work to the two groups, the practice was discontinued as being unsatisfactory as there was too great a variation in the quantity and the quality of chemistry presented for admission to make such separation effective. However, since many students felt that they had received an adequate high school course and were being penalized by compulsory assignment to a section where previous chemistry was not required, an option of taking an accelerated one-semester course was offered in lieu of the standard beginning course. Of the advantage conferred by having had high school chemistry, Martin said,

> Although the elementary course is specifically planned to meet the needs of those who have no previous training in chemistry, statistics over a period of several years indicated that the percentage of failures in the group which had not had high school chemistry was significantly higher than in the group which had taken chemistry in high school.[18]

Martin qualified his conclusion by raising the question that perhaps insufficient preparation in mathematics may have been just as responsible as the lack of high school chemistry and was probably the factor that caused most of them to avoid chemistry in high school when it could have been elected.

The value of high school grades for prediction of probable success in college is still far from settled. Dyer, in 1945, in an effort to

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[17] Martin, p. 275.

[18] Ibid., p. 276.

validate the Armed Forces Institute Tests of General Educational Development, reported,

> Great disparity has been found between the college grades of groups of students who came from different high schools, but who had similar high school grades. As a result many of the larger colleges and universities have adopted the practice of keeping careful records of their students grouped according to the high school from which they originated.[19]

Travers, writing four years later, is just as certain of the opposite. He said,

> At the present time, the evidence indicates that the best single measure for the selection of the college student is his average grade in high school. . . . The value of high school grades for predictive purposes is undoubtedly a result of the fact that they represent a combination of abilities and motivational factors operating in much the same way as they will operate in college.[20]

The superior performance in college chemistry by those who had previously had high school chemistry is fairly evident from the literature but continues to be a subject of investigation. At Purdue, in 1942, Martin fairly well established the superior performance of the group who had previously had chemistry, although variations in performance prompted discontinuance of separate sections for the two categories of students. At Southern Illinois University a study by Hadley, Scott, and Van Lente, in 1953, reached the following conclusions: (1) students who had a combination of high school chemistry, physics, and mathematics made the best records in their beginning college chemistry course; (2) students who had high school chemistry, irrespective of other courses,

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[19] H. S. Dyer, "Evidence on the Validity of the Armed Forces Institute Tests of General Educational Development (College Level)," <u>Educ</u>. <u>Psy</u>. <u>Meas</u>., 5 (1945), 321-23.

[20] Travers, p. 154.

made better records than those who did not have high school chemistry; but (3) it was not possible to determine how much of this was due to the high school courses themselves and how much to other factors.[21]

Performance of students with and without high school chemistry at the University of Minnesota, reported by Brasted in 1957, bears out the contention of previous investigators that the performance of the student with high school chemistry is higher than that of the student without the same training, but he leaves a note of doubt as to the cause when he says,

> The primary point of contention now seems to be whether students with this preparation are inherently of a better grade or whether the preparatory work in high school has led to better achievement in college chemistry.
>
> Although it cannot be claimed that the student retained factual knowledge gained in the preparatory course in the exact sciences, it is obvious that these courses greatly influenced his accomplishment in college chemistry.[22]

There is still doubt in the minds of some investigators of the adequacy of high school rank or performance in high school chemistry as indexes of performance in the college course. Hovey and Krohn, at the University of Toledo, as late as October, 1958, reported,

> No useful correlation was found between rank in high school graduating class and success in Chemistry 17, nor were high school chemistry grades a reliable indication of college chemistry performance.[23]

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[21] E. H. Hadley, R. A. Scott, and K. A. Van Lente, "The Relationship of High School Preparation to College Chemistry Grades," _J. Chem. Ed._, 30 (1953), 311-13.

[22] Robert C. Brasted, "Achievement in First Year College Chemistry Related to High School Preparation," _J. Chem. Ed._, 34 (1957), 562-65.

[23] Hovey and Krohn, p. 509.

They did qualify their conclusion somewhat when they remarked that grades from large high schools were more meaningful than those from small schools. Their study, begun in the fall of 1954, advocates administration of a chemistry aptitude test, and despite their statement that high school chemistry grades were not reliable predictors, one year of high school chemistry and one year of algebra were pre-requisites for the course in which the study was made.

Thus it seems clear that if students have pursued the study of chemistry and algebra for one year and still cannot exceed a low minimum score on a chemistry aptitude test, one is justified in having them avoid chemistry, even if it means changing their professional goals. Those, so restrained at Toledo, are allowed to enroll in a pre-college course that meets two hours per week for one semester for no credit. If satisfactory performance is established, they are permitted to enroll in the standard course. Hovey and Krohn feel that the arrangement is a satisfactory one, for the doubtful student is spared the frustration of trying to take a course beyond his capacity in the first semester at the university. They state further,

> We realize no method would be entirely satisfactory because we could not predict motivation and numerous other factors which cause a well qualified student to fail or a poorly qualified student to rise above the expected level. Despite some errors in placement, we felt that much good would be accomplished if most who would have failed could be steered into other channels.[24]

More Recent Studies

In every case, the studies made within the past ten years, with the exception of that of Brasted, at the University of Minnesota, in 1957,

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and that of Hadley, Scott, and Van Lente, at Southern Illinois University, in 1953, have by-passed the evidence presented by the high school transcript itself, and attempts have been made to establish reliance on performance of the student on some type of examination given at admission to the college. A study begun in September, 1948, at Michigan State College was concerned with the relation between success in their freshman chemistry course requiring no high school chemistry and the ability to perform the fundamental arithmetic operations and to read material involving chemistry. All entering chemistry students were administered the A.C.E. Psychological Examination and the Michigan State College Chemistry Pre-Test. At the completion of the course their grades were correlated with their scores on the two tests. Jackson says of the results.

> These correlations show that success in the course is related to the two abilities, i.e. to performing fundamental arithmetic operations, and to reading appropriate material. An attempt was then made to determine scores for these tests by which students could be selected for the course. Those failing to meet these standards were given remedial work before being allowed to enroll in the course.[25]

In a later report, in 1955, Jackson reported that the admissions test for chemistry had been expanded to include: (1) the A.C.E. Psychological Examination, (2) a reading test developed by Michigan State College, (3) a test of English usage, and (4) an arithmetic proficiency test.[26]

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[25] Robert A. Jackson, "The Selection of Students for Freshman Chemistry by Means of Discriminant Functions," Journ. of Exper. Edu., 18 (1950), 209-14.

[26] Robert A. Jackson. "Prediction of the Academic Success of

Merzbacher reported a similar study made at San Diego State College. The purpose of the study was to determine the correlation between performances in the existing freshman testing program and success in beginning college chemistry. The data was used merely for counseling. Tests given were the A.C.E. Psychological Examination and the Iowa High School Content Examination. Beginning chemistry students' means in percentiles were compared with the entire freshman class on (1) the quantitative section of the A.C.E. Psychological Examination, (2) the mathematics section of the Iowa High School Content Examination, and (3) the science section of the latter examination. In every case the beginning chemistry students' means were superior to the means of the entire freshman class by approximately twenty-five percentile points. At the end of the semester, the following correlations were obtained: chemistry grade and quantitative section score, 0.447; chemistry grade and science section score, 0.464; and science section score and quantitative section score, 0.310. Merzbacher's comments on the results were:

> The best correlations were found with the quantitative score on the Psychological Examination, and with the science section score on the I.H.S.C.E. As might be expected, the correlation of chemistry grades with quantitative reasoning ability was comparatively high. The "problem-solving" technique, and the "principle-finding" ability measured by this test were both apparently important in success in chemistry.[27]

Elton, reporting from the University of Mississippi, in 1956, took a dim view of the necessity for an elaborate psychological and content examination at admission. Becoming alarmed at a sudden increase in the

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[27] Claude Fell Merzbacher, "Correlation Between the Freshman Testing Program and First Semester Chemistry at San Diego State College," J. Chem. Ed., 26 (1949), 466-70.

drop-rate of students in his department in the fall of 1955--two weeks before the end of the semester 232 students remained after eighty-three had dropped out--he decided to evaluate the importance of the level of achievement in arithmetic and algebra as a contributing factor in the failure of beginning students. A fifteen-item arithmetic test (Kinzer) was administered, and at the end of the semester, performance on the test was compared with the chemistry grade received. Seventy-two students (30 per cent of the 232 remaining on the rolls) who worked fewer than eight of the fifteen problems got F or D in chemistry, while eight students (three per cent) working the same number of problems, got C or B in the course. Elton reasoned that if the test had been given as a pre-requisite for admission and eight or more correct answers on the arithmetic test had been required for admission, the mortality would have been thirty-three per cent instead of sixty-three per cent. To be sure, he said this would have excluded the eight students who made C or better, but this was a mere three per cent of the class. He also presented evidence to show that five items on the Kinzer test correlated as high with final chemistry grades as did all fifteen items, and he was of the opinion that a five-problem test--the problems involving substitution in formulas, calculation of percentage, finding values of complex fractions, and the use of decimals--can be used effectively and efficiently to deny admission to those with less than minimum mathematical proficience and thereby reduce the mortality rate in beginning college chemistry.[28]

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[28]Charles F. Elton, "The Expectancy Table--A Device to Demonstrate

Implications Leading to this Study

Evidence from the literature is near total agreement on only one factor, that the performance of the student with previous instruction in chemistry is higher than that of the student without the same training. Since, in the average section of college chemistry, these make up approximately one-half of the membership, what method or methods of assay of the potential success of the other half of the group in this subject would be most profitable to employ? Where little has been done previously in this area, could not existing entrance examination scores be used to predict the performance in chemistry of the student who has had no previous experience in this subject?

CHAPTER III

DESIGN OF THE EXPERIMENT

Selection of a Population

In order to examine the hypothesis that there is a relationship between marks received in Chemistry 114 at Oklahoma State University and scores made on achievement tests taken there at the time of entrance, it was first necessary to select a population for study. After criteria for this selection were established, and an acceptable sample was obtained, necessary data was gathered and analyzed.

The study extended over four consecutive fall semesters, beginning in 1954 and was concluded with the 1957 class. The assumption was made that once the correlative data was obtained, a regression equation relating the dependency of the final grade on the results of each of the achievement tests could be written. This regression equation would be of the standard form,

$$Y = X_1' = a_o + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5$$

where Y would be the predicted final grade in Chemistry 114; the X's, the raw scores on the various achievement tests; the b's, the weights showing the variation in Y accounted for by variations of the X-values; and a_o, the intercept constant.

The master rolls for Chemistry 114 for each of the fall semesters for the years 1954, 1955, 1956, and 1957 were used as the fundamental source of data for the selection of the population studied. These contained, in addition to other information, the names and classification of every student that enrolled in the course, including those who dropped or otherwise failed to continue in attendance, and the final numerical grade for each student that remained throughout the semester.

The first criterion, freshman classification at the time of enrollment, was applied, and in case of doubt the classification was verified at the office of the registrar. Cases meeting the first criterion were examined to determine (1) if their secondary school work has been done in the continental United States and (2) if they had had previous instruction in chemistry. This information was obtained from cards in the files of the Chemistry Department, but, where information was lacking it was obtained from the transcript of the student's credits in the registrar's office.

Materials

The achievement tests, which are now administered at Oklahoma State University or were administered during the years of the study and scores on which were used as the independent variables in the calculation of the regression equation, are (1) the American Council on Education Psychological Examination, 1948 edition for college freshmen; (2) the School and College Ability Test, College Ability Test, Form I-A; (3) the Psychological Corporation Language Usage Test, Form B (1947), Part II (sentences only), and (4) the Cooperative Elementary Algebra Test, Revised Form Z.

Students during the first three years of the study, 1954 through

Examination, but since the summer of 1957 the School and College Ability Test has been in use. This necessitated separating the study into two populations corresponding to the evaluation instrument that was being used at the time the student matriculated. Converting scores on one of these examinations into equivalent scores on the other would have simplified the procedure, but in the interest of accuracy the obtained scores were used, and two separate regression equations were calculated. The Language Usage Test and the Elementary Algebra Test were used throughout the four years of the study.

Test scores on (1) the quantitative section, and (2) the linguistic or verbal section of the Psychological Examination, or the Ability Test, were obtained from the files of the Tests and Measurements Bureau. The English test scores were secured from the files of the English department. Algebra test scores that were not on file in the Tests and Measurements Bureau were obtained directly from the Department of Mathematics. These scores in raw-score form were used as the independent variables, X_2, X_3, X_4, and X_5, in the calculation of the regression equation.

The numerical grade received in Chemistry 114 was obtained from the master rolls for this course and were used as the dependent variable in the regression equation calculation. Incomplete or withheld grades and technical failures, due mainly to non-attendance in the closing phases of the course or to scholastic dishonesty, were not used since a letter designation without any basis for a numerical value had been assigned in these cases.

Treatment of the Data

Once the primary data had been secured and tabulated, it was subjected to statistical analysis in order to describe certain pertinent characteristics of the samples.

I. Population Analysis: A. In order to describe the atrrition rates of the four classes, the number of students initially enrolled in Chemistry 114 and the number receiving a final grade was determined and compared.

B. The percentage of the final membership of each class that had received no previous instruction in chemistry prior to enrollment in the course and the percentage of the four classes as a whole was determined.

C. The percentages of each of the two populations (those with and those without previous chemistry instruction) achieving passing marks in each of the four classes, and for the four classes as a group, were calculated.

D. The numerical grade of each student was converted into a letter grade on the basis of the college scale, and then a letter-grade distribution of the entire class was made for each of the four years selected for this study. Similar grade distributions were prepared for students with and students without previous chemistry instruction.

E. Since it was already known that many of the test scores were lacking, it was necessary to make a comparison of the mean chemistry grades of those lacking certain test scores, but otherwise meeting the criteria, with the mean chemistry grades of those with all test scores complete. This was done for each of the two populations: (1) those who were administered the American Council on Education Psychological

Examination for each of the three years, 1954, 1955, and 1956, and for the group taken as a whole; and (2) those who were given the School and College Ability Test, for the single year, 1957. Critical ratios were calculated between (1) the mean chemistry grade achieved by those whose scores are missing (a) on the psychological examination, (b) the English test, and (c) the algebra test, and (2) the mean chemistry grade achieved by those with all test scores complete.

II. Data Analysis: A. For those with all test scores complete, correlation coefficients between test scores and chemistry grades were calculated. Separate calculations were made for the two populations: the 1954, 1955, and 1956 classes as comprising one group, and the 1957 class, the other.

B. The regression equation, including all variables, was calculated for Population I (1954-1956), and the t-test applied to the regression weight of each of the independent variables in order to determine those which had significance.

C. If one or more of these variables lacked significance, the regression equation was re-calculated, and the standard error of estimate was determined, using only the independent variables that meet the test of significance.

D. The multiple correlation coefficient involving only the significant independent variables was calculated for the three classes, 1954-1956, combined.

E. Identical calculations, as made for the 1954-1956 classes, were made for the 1957 class, namely, (1) regression equation including all variables; (2) regression equation and standard error of estimate including only the variables shown to be significant; and (3) the multiple correlation coefficient involving only the significant variables.

Calculations

To determine whether there was a significant difference in the mean chemistry grades of the two populations, those meeting all criteria and those with certain test scores missing, the following formula was used:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\sigma_{M_1}^{\,2} + \sigma_{M_2}^{\,2}}}$$

where $\overline{X}_1 - \overline{X}_2$ was the difference in the mean chemistry grades, and σ_{M_1} and σ_{M_2} were the standard errors of each of the means. The standard error in each case was calculated from the formula,

$$\sigma_{M_1} = \frac{\sigma_1}{N_1} \quad \text{and} \quad \sigma_{M_2} = \frac{\sigma_2}{N_2}$$

σ_1 and σ_2 refer to the standard deviations of the two means involved, and N_1 and N_2 were the numbers of cases involved in each population.

The beta-coefficients for use in the calculation of multiple coefficients of correlation were calculated from the partial regression coefficients obtained from the regression equation as follows:

$$\beta_{12.34\,\ldots\ldots n} = b_{12.34\cdot\cdots\cdot n}\,\frac{\sigma_2}{\sigma_1}$$

To calculate the multiple coefficient of correlation for three variables the following equation was used:

$$R = \sqrt{R^2} = \sqrt{\beta_{12.3}\, r_{12} + \beta_{13.2}\, r_{13}}$$

CHAPTER IV

FINDINGS

Population Analysis

The final sample which met all of the criteria established before the study was started was composed of students who registered for Chemistry 114 at Oklahoma State University during one of the four fall semesters (1954-1957), remained in attendance throughout the semester, and received a final numerical grade. In addition, each was classified as a freshman at the time of enrollment, each had attended secondary school in the continental United States, each had received no previous instruction in chemistry before he had enrolled. Also, each had taken the achievement tests required of freshmen, and the score made on each part of the test was on record.

As the successive steps outlined under Treatment of Data for Population Analysis (Chapter III) were taken, the original size of the sample, which was the total initial enrollment for the four years of the study, decreased from 2,994 to a final sample size of 745. This latter figure represents the total number during the four years that met all the criteria. The magnitude of the first decrement is revealed in Table I. An average of 8.8 per cent of the initial enrollment each year dropped out before the end of the semester during the four years that were considered. This factor alone caused the raw sample size to decrease from 2,992 to 2,761.

Although the study was designed primarily to predict the performance of those without previous chemistry, analysis of the population revealed that slightly less than half the membership of each class had not previously studied chemistry. In Table II was recorded the relative numbers of the two populations.

During the four years of the study 92 failures were recorded out of the 1,526 grades that were made by those who had previously studied chemistry, but 166 failing grades were received among the smaller population of the 1,235 who had enrolled without previous instruction in chemistry. These findings are reported in Table III.

Tables IV, V, and VI, extend the analysis of the possible advantage of previous study of chemistry prior to enrollment at Oklahoma State University.

If the assumption is made that the distribution of abilities was approximately the same throughout the four years and that individual application was also fairly constant, it is seen from Table IV that the marks assigned did not depart too seriously from the normal distribution.

Table V portrays the achievement indicated by the marks received by one of the two populations, namely all of those who had previous instruction in chemistry.

When comparisons are made between Tables IV and V, it is readily apparent that the group with previous chemistry received a higher percentage of A's and B's, did about as well or slightly better in the number of C-grades, and got considerably fewer D's and F's than would have been obtained by a group of the same size selected at random from the entire class.

The apparent superior performance of the group who had previous

TABLE I

INITIAL ENROLLMENT AND MEMBERSHIP AT END OF FALL SEMESTER BY YEARS

CLASS	TOTAL ENROLLMENT		FINAL MEMBERSHIP	
	Number	Percentage of four-year total	Number	Percentage of final membership
1954	677	22.6%	614	90.7%
1955	759	25.3	719	94.7
1956	800	26.7	710	88.8
1957	758	25.3	718	94.7
Total	2994	99.9%	2761	92.2%

TABLE II

PROPORTION OF FINAL MEMBERSHIP WITHOUT PREVIOUS CHEMISTRY

CLASS	FINAL MEMBERSHIP	NUMBER WITHOUT PREVIOUS CHEMISTRY	PERCENTAGE OF FINAL MEMBERSHIP
1954	614	288	46.9%
1955	719	341	47.4
1956	710	314	44.2
1957	718	292	40.7
Total	2761	1235	44.7%

TABLE III

COMPARISON OF PERCENTAGES OF PASSING MARKS FOR THOSE WITH AND THOSE WITHOUT PREVIOUS CHEMISTRY

CLASS	Percentage of Final Enrollment Passing	
	Without Previous Chemistry	With Previous Chemistry
1954	91.3%	92.0%
1955	88.6	94.4
1956	88.2	97.5
1957	77.7	92.0
Total	86.6%	94.0%

TABLE IV

LETTER GRADE DISTRIBUTION OF ENTIRE CLASS BY YEARS

CLASS	A	B	C	D	F
1954	8.8%	24.1%	37.1%	21.7%	8.3%
1955	10.0	20.3	43.0	18.4	8.3
1956	8.6	24.2	39.7	20.8	6.6
1957	11.6	20.9	36.1	17.7	13.8
Total	9.8%	22.3%	39.0%	19.6%	9.6%

TABLE V

LETTER GRADE DISTRIBUTION OF ALL OF THOSE
WITH PREVIOUS CHEMISTRY

CLASS	A	B	C	D	F
1954	12.6%	27.0%	35.3%	17.2%	8.0%
1955	12.4	22.2	47.4	12.4	5.6
1956	11.6	28.8	40.4	16.7	2.5
1957	15.5	26.6	35.9	14.1	8.0
Total	13.1%	26.1%	39.8%	15.0%	6.0%

TABLE VI

LETTER GRADE DISTRIBUTION OF FRESHMEN
WITHOUT PREVIOUS CHEMISTRY

CLASS	A	B	C	D	F
1954	4.5%	20.9%	39.2%	26.7%	8.7%
1955	7.3	18.2	38.1	24.9	11.4
1956	4.8	18.5	38.9	26.1	11.8
1957	5.8	12.7	36.3	22.9	22.3
Total	5.7%	17.6%	38.1%	25.2%	13.4%

chemistry is very pronounced when comparisons are made with the other population, freshmen (only) who had no previous instruction in chemistry prior to enrollment. Their achievement is indicated in Table VI.

The quality of the passing mark for those without previous instruction in chemistry as compared to the other population, those who had received previous instruction in the subject, can be approximated roughly as follows: Population II the group with previous instruction made nearly three times as many A's, one and one-half times as many B's, and about the same number of C's as Population I. This latter group made nearly twice as many D's as the former, and over twice as many F's.

There was a possibility that the absence of complete test scores for a student might introduce a bias in the relationship being examined. In view of this possibility an analysis of this situation was made. A complete set of test scores for the beginning student consists of (1) three scores on the A.C.E. Psychological Examination or the School and College Ability Test, as follows: the score on the quantitative section, the score on the linguistic or verbal section, and the total of the foregoing two scores combined: (2) a score on the English examination; and (3) a score on the algebra test. The total score on neither the Psychological Examination nor the Ability Test was used since the component parts, the Q- and the L-score, were thought to be individually significant. Examination of the data in Table VII reveals the approximate success an investigator can expect for the period covered.

Extensive search of records failed to reveal either the missing test scores or the reasons for their omission. This did not prove disastrous to the study but made it necessary to determine whether this factor would adversely affect the results.

Tables VIII, IX, X, and XI afford an opportunity to compare the mean chemistry grade of those lacking the A.C.E. Psychological Test scores, the English score, and the algebra score, respectively, with the mean chemistry grade of those with all test scores complete, together with the standard deviation of each of the means. These four Tables, VIII-XI, cover the three-year period when the American Council on Education Psychological Examination was given at matriculation as a measurement of secondary school achievement. The algebra and English tests used were the same throughout the period covered in the study.

When the hypothesis--the differences in the means of the chemistry grades is not biased due to the lack of certain test scores but is due to chance variation alone--was examined the results shown in Table XII were obtained. Here it was seen that only one critical ratio, that obtained from the combined group without algebra test scores, barely exceeded the .05 level of significance (which for samples of this size is 1.96). Consequently, the null hypothesis was not rejected, for the obtained differences were not significant, and the lack of certain test scores did not bias the results when this portion of the population was not included in the final sample.

The 1957 class was also found to have many of their test scores missing. It thus became necessary to determine to what extent the various scores were lacking and to use the same procedure as had been used for the 1954-1956 classes in order to find out whether the lack of test scores was a biasing factor or if the variations were due to chance alone. Table XIII enables one to compare the percentage that lacked each of the scores with the percentage from the previous classes

TABLE VII

PERCENTAGES OF COMPLETE AND INCOMPLETE TEST SCORES AND THEIR CATEGORIES

Year	Percentage with Complete Test Scores	Percentage with Incomplete Test Scores		
		Psychological Exam	English Exam	Algebra Exam
1954	62.5%	7.3%	18.1%	26.8%
1955	62.0	8.2	24.0	20.6
1956	55.5	6.7	35.7	21.0
1957	61.7	10.6	21.6	26.0
Total	60.3%	8.2%	25.0%	23.6%

TABLE VIII

MEAN CHEMISTRY GRADES AND THEIR STANDARD DEVIATIONS FOR THOSE WITH ALL TEST SCORES COMPLETE

Year	Number With All Scores	Percentage With All Scores	Mean Grade	Standard Deviation
1954	180	62.5%	79.8	7.4
1955	211	62.0	79.1	7.2
1956	174	55.5	79.0	7.5
Total	565	59.0%	79.3	7.4

TABLE IX

MEAN CHEMISTRY GRADES AND THEIR STANDARD DEVIATIONS
FOR THOSE LACKING PSYCHOLOGICAL TEST SCORES

Year	Percentage Lacking This Score	Mean Grade	Standard Deviation
1954	7.3%	80.1	5.6
1955	8.2	79.8	8.5
1956	6.7	75.8	7.9
Total	7.4%	78.7	7.8

TABLE X

MEAN CHEMISTRY GRADES AND THEIR STANDARD DEVIATIONS
FOR THOSE LACKING ENGLISH TEST SCORES

Year	Percentage Lacking This Score	Mean Grade	Standard Deviation
1954	18.1%	80.5	7.2
1955	24.0	79.6	8.7
1956	35.7	77.5	7.8
Total	26.1%	78.8	8.1

TABLE XI

MEAN CHEMISTRY GRADES AND THEIR STANDARD DEVIATIONS FOR THOSE LACKING ALGEBRA TEST SCORE

Year	Percentage Lacking This Score	Mean Grade	Standard Deviation
1954	26.8%	77.6	8.3
1955	20.6	79.6	8.4
1956	21.0	76.8	7.9
Total	22.6%	78.0	8.3

TABLE XII

CRITICAL RATIOS BETWEEN MEAN CHEMISTRY GRADES OF THOSE WITH AND THOSE WITHOUT COMPLETE TEST SCORES

Test Score Missing	Year			Three Years Combined
	1954	1955	1956	
A.C.E.P.E.	0.72	0.42	1.21	0.61
English	1.07	0.46	1.61	0.83
Algebra	1.34	0.47	1.95	2.00

TABLE XIII

PERCENTAGE OF TEST SCORES MISSING, THE MEAN CHEMISTRY GRADE ACHIEVED BY EACH GROUP, AND ITS STANDARD DEVIATION

Test Score Missing	Percentage	Mean Grade	Standard Deviation
S.C.A.T.	10.6%	78.1	6.6
English	21.6	77.8	8.0
Algebra	26.0	75.5	9.2
None (N = 180)	61.7%	77.4	8.9

TABLE XIV

CRITICAL RATIOS BETWEEN MEAN CHEMISTRY GRADES OF THOSE WITH AND THOSE WITHOUT COMPLETE TEST SCORES IN 1957

(N = 180)

Test Score Missing	Critical Ratio
Ability Test	0.51
English Test	0.33
Algebra Test	1.55

lacking these same scores (Tables IX, X, and XI). This Table allows a comparison of the mean chemistry grade achieved by those missing certain test scores with the mean grade obtained by those whose test scores were complete.

A slightly larger percentage of students was lacking the Ability Test score than had been lacking the Psychological Examination score during the three years preceding, and the same situation existed with reference to the algebra score. The percentage of students that lacked the English score was considerably lower, however, than it was in any of the three previous years.

As with the preceding classes (1954, 1955, and 1956), the hypothesis, the differences in the means is not biased due to the lack of certain test scores but is due to chance variation alone, was examined for the 1957 class. The results are given in Table XIV.

None of the critical ratios exceeded the .05 level of significance (which for samples of this size is 1.96). Consequently, the null hypothesis was not rejected.

Data Analysis

The final sample size from which the regression equations and other pertinent findings were calculated was made up of 745 students who met all of the criteria. These actually represent two sub-groups, 565 from the initial membership of 2,236 for the 1954-1956 classes, and 180 from the 758 who initially enrolled in Chemistry 114 in the fall of 1957. The basis for the separation was the difference in the achievement tests that had been administered.

When data cards for the final sample from the 1954-1956 classes were prepared for use on the I.B.M. 650 Computer, the chemistry grade was used as the dependent variable, X_1. The independent variables were X_2 and X_3, the Q-score and L-score, respectively, from the Psychological Examination; X_4, the English score; and X_5, the algebra score. When the data was processed, the correlation found between each of the test scores and the chemistry grade, as well as the correlation of test scores with each other, was obtained. The results are shown in Table XV.

Three of the correlation coefficients, those between (1) the Q-score and the English score, (2) the chemistry grade and the English score, and (3) the chemistry grade and the Q-score, were found to be in the range 0.30 to 0.39. Two of the coefficients, English score versus algebra score and chemistry grade versus L-score, are in the 0.40 to 0.49 range. The other five correlation coefficients are in the range 0.50 to 0.60.

Data cards for the final sample from the 1957 class were prepared in a similar fashion, except X_2 and X_3 were the Q-score and V-score, respectively, on the College Ability Test. When the data was processed, the results shown in Table XVI were obtained.

The correlation coefficients were found to be significantly higher for the single year (1957) for which the School and College Ability Test was used. Whereas only five of the intercorrelation coefficients in Table XV were in the 0.50 to 0.60 range, nine of the ten in this series were in this range, or higher. Actually, four of the ten were in the 0.60 to 0.70 range.

When the regression equation was put in raw-score form,[1]

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[1] X_1' is the calculated chemistry grade; a_0 the intercept constant; X_2, the Q-score on the A.C.E. Psychological Examination; X_3, the L-score on the same examination; X_4, the English score; and X_5, the algebra score.

TABLE XV

INTERCORRELATION COEFFICIENTS OF TEST SCORES AND CHEMISTRY GRADES FOR THREE YEARS, 1954-1956[a]

(N = 565)

	X_2	X_3	X_4	X_5	X_1
X_2					
X_3	0.51				
X_4	0.31	0.56			
X_5	0.60	0.51	0.43		
X_1	0.38	0.48	0.37	0.58	
M_x	43.0	57.2	41.9	26.5	79.3
S.D.	10.2	13.9	13.8	12.7	7.8

[a] X_1, the dependent variable, is the chemistry grade; X_2, the Q-score on the A.C.E.P.E.; X_3, the L-score on the same examination; X_4. the English score; and X_5, the algebra score.

TABLE XVI

INTERCORRELATION COEFFICIENTS OF TEST SCORES AND CHEMISTRY GRADES IN 1957[b]

	X_2	X_3	X_4	X_5	X_1
X_2					
X_3	0.41				
X_4	0.51	0.61			
X_5	0.68	0.50	0.52		
X_1	0.64	0.53	0.54	0.63	
M_x	304.1	290.0	41.3	24.9	77.2
S.D.	15.1	15.1	14.2	12.3	9.0

[b]X_1, the dependent variable, is the chemistry grade; X_2, the Q-score on the S.C.A.T.; X_3, the V-score on the same test; X_4, the English score; and X_5, the algebra score.

$$Y = X_1' = a_o + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 \tag{1}$$

and the data cards for the 1954-1956 classes were used to solve it for the various regression-weights and the constant, the results in Table XVII were obtained. As a concession to accuracy this analysis was carried out on the I.B.M. 650 Computer.

When the values shown in Table XVII are substituted in the original equation, the following equation is obtained:

$$Y = X_1' = 64.11 - .0267X_2 + .1297X_3 + .0355X_4 + .2805X_5 \tag{2}$$

When the regression weight for each of the independent variables in Equation (2) is tested for significance by examining the null hypothesis, none of the regression-weights differ significantly from zero, the results shown in Table XVIII are obtained.

The null hypothesis was retained in two of the four cases being tested, $\underline{b}_2$ and $\underline{b}_4$, both of which failed to be significantly different from zero. On the other hand, $\underline{b}_3$, the linguistic score regression weight, and $\underline{b}_5$, the algebra-score regression-weight, are significant beyond the .01 level, which is 2.59 for a sample of the size under consideration (N = 565).

The data cards were re-run on the computer with X_2, the quantitative score on the psychological examination, and X_4, the English score deleted. This gave a solution to the following equation:

$$Y = X_1' = a_o + b_3X_3 + b_5X_5 \tag{3}$$

where all of the symbols used have the same identity as before. The values obtained for the constant and the two regression weights, and the standard error of estimate are shown in Table XIX.

When the values shown in Table XIX are substituted in Equation (3) the following equation is obtained:

$$Y = X_1' = 63.89 + .1406X_3 + .2779X_5 \qquad (4)$$

The b-coefficients give the weights to be accorded the scores used as the independent variables X_3 and X_5, but not the contribution of these variables without regard to the scoring system employed in each of the tests. This latter contribution is given in the "beta weights," or beta coefficients. The beta coefficients also enable one to readily calculate R^2 from which the multiple correlation coefficient R may be obtained. These calculations are shown in the Appendix. The results of the calculations are shown in Table XX.

The contribution of the algebra test score is nearly twice that of the linguistic score in predicting the most probable chemistry grade that a given student is most likely to achieve.

When the regression equation was put in raw score form,

$$Y = X_1' = a_o + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 \qquad (1)$$

and the data cards for the 1957 class used to solve it for the various regression weights and the constant, by means of the Regression Analysis Program on the I.B.M. 650 Computer, the results shown in Table XXI were obtained.

When the values shown in Table XXI are substituted in the original equation (1), the following equation is obtained:

$$Y = X_1' = -25.27 + .1987X_2 + .1206X_3 + .0719X_4 + .1765X_5 \qquad (5)$$

When the regression weight for each of the independent variables in Equation (5) is tested for significance, the results shown in Table

TABLE XVII

REGRESSION WEIGHTS AND RESIDUAL CONSTANT FOR 1954-56 CLASSES, INCLUDING ALL VARIABLES

$a_o = 64.11$	$b_4 = 0.0355$
$b_2 = -0.0267$	$b_5 = 0.2805$
$b_3 = 0.1297$	S.E. = $\pm$ 6.2

TABLE XVIII

RESULTS OF TESTS OF SIGNIFICANCE FOR REGRESSION WEIGHTS (1954-56)

Regression Weight	t
b_2	0.79
b_3	5.08
b_4	1.53
b_5	10.35

TABLE XIX

REGRESSION WEIGHTS AND RESIDUAL CONSTANT FOR 1954-1956 CLASSES, INCLUDING ONLY THE TWO SIGNIFICANT VARIABLES

Item	Magnitude
a_o	63.89
b_3	.1406
b_5	.2779
S.E.	± 6.2

TABLE XX

BETA COEFFICIENTS AND THE COEFFICIENT OF MULTIPLE CORRELATION FOR THREE VARIABLES (1954-56)

$$B_{13.5} = 0.25$$

$$B_{15.3} = 0.45$$

$$R^2_{1.35} = 0.38$$

$$R_{1.35} = 0.62$$

TABLE XXI

REGRESSION WEIGHTS AND RESIDUAL CONSTANT FOR 1957 CLASS, INCLUDING ALL VARIABLES

Item	Magnitude
a_o	-25.27
b_2	.1987
b_3	.1206
b_4	.0719
b_5	.1765
S.E.	± 6.2

TABLE XXII

RESULTS OF TESTS OF SIGNIFICANCE FOR REGRESSION WEIGHTS (1957)

Regression Weight	t
b_2	4.6
b_3	3.0
b_4	1.6
b_5	3.2

The null hypothesis was retained in only one of the four cases being tested, b_4, which failed to be significantly different from zero, even at the .10 level. On the other hand, b_2 and b_3, quantitative score and linguistic score coefficients, respectively, and b_5, the algebra score regression weight are significant beyond the .01 level, which require a value of 2.60 for a sample of the size under consideration (N = 180).

The data cards for the 1957 class were re-run on the computer with X_4, the English score, deleted. This gave a solution to the following equation:

$$Y = X_1' = a_o + b_2X_2 + b_3X_3 + b_5X_5 \qquad (6)$$

where the symbols that are used have the same identity as before. The values obtained for the constant and the two regression weights, and the standard error of estimate that were obtained are shown in Table XXIII.

When the values shown in Table XXIII are substituted in Equation (6), the following equation is obtained:

$$Y = X_1' = -36.17 + .2139X_2 + .1507X_3 + .1881X_5 \qquad (7)$$

The _b_ coeffieients were transformed into "beta weights," or beta coefficients in order that the contributions of the various variables might be estimated. The beta coefficients were then used to calculate $R^2_{1.235}$, from which the coefficient of multiple correlation, $R_{1.235}$, was obtained. These calculations are shown in the Appendix. The results of the calculations are shown in Table XXIX.

The contribution of the quantitative section score of the College Ability Test is greater than either the linguistic section of the same test or the algebra test in predicting the most probable chemistry grade that a given student is most likely to achieve. The coefficient

TABLE XXIII

REGRESSION WEIGHTS AND RESIDUAL CONSTANT FOR 1957 CLASS, INCLUDING ONLY THE THREE SIGNIFICANT VARIABLES

Item	Magnitude
a_o	-36.17
b_2	.2139
b_3	.1507
b_5	.1881
S.E.	± 6.2

TABLE XXIV

BETA COEFFICIENTS AND THE COEFFICIENT OF MULTIPLE CORRELATION FOR FOUR VARIABLES (1957)

$$B_{12.35} = 0.35$$

$$B_{13.25} = 0.25$$

$$B_{15.23} = 0.26$$

$$R^2_{1.235} = 0.52$$

$$R_{1.235} = 0.73$$

of multiple correlation, 0.73, exceeds the value, 0.14, which is required for significance at the .01 level.

CHAPTER V

DISCUSSION

This study was concerned with two basic purposes: The selection of a population for study, and designing a procedure to determine if a relationship existed between marks received in Chemistry 114 at Oklahoma State University and the scores made on achievement tests taken at matriculation. To fulfill these purposes the data was summarized and certain calculations were made from it as follows:

I. Population Analysis: (1) In order to describe the attrition rates of the four classes, the number of students who had initially enrolled in Chemistry 114 and the number that received a final grade were determined and compared.

(2) The percentage of the final membership of each class that had received no previous instruction in chemistry prior to enrollment in the course, and the percentage of the four classes as a whole who had not received prior instruction was determined.

(3) The percentages of each of the two populations (those with and those without previous chemistry instruction) achieving passing marks in each of the four classes, and for the four classes as a group were calculated.

(4) The numerical grade of each student was converted into a letter grade on the basis of the college scale, and then a letter-grade distribution of the entire class was made for each of the four years, 1954-1957.

(5) A comparison was made between the mean chemistry grade of those lacking certain test scores, but otherwise meeting the criteria, with the mean chemistry grades of those with all test scores complete.

II. Data Analysis: Two sub-groups, one with a population of 565 (from the 1954-1956 classes) and the other with a population of 180 fro the 1957 class, met the criteria for selection, and data from these wer used as follows:

(1) Correlation coefficients between each of four test scores and the chemistry grade were calculated. Separate calculations were made for the two populations.

(2) A regression equation whereby chemistry grades might be calculated from scores on the four admission tests was calculated for Population I (1954-1956), and the t-test was applied to the regression weight of each of the independent variables in order to determine which were significant.

(3) The regression equation based on the data for Population I was re-calculated, and the standard error of estimate was determined, using only the independent variables that met the test of significance.

(4) The multiple correlation coefficient involving only the significant independent variables was calculated for Population I, the combined 1954-1956 classes.

(5) Identical calculations for the 1957 class were made as for th 1954-1956 classes, namely, regression equation including all variables, regression equation and standard error of estimate including only the variables shown to be significant, and the multiple correlation coefficient involving only the significant variables.

the drop rate (7.8 per cent), and the failure rate (9.6 per cent) has not been excessive as judged by reports of similar studies made at other institutions. On the other hand, these figures indicate that nearly one student out of every five that presently enrolls in Chemistry 114 will either drop or fail the course. The final membership in each year has been remarkably stable and close to 700. No trend is detectable in the drop-rate of the four classes, as the percentage of total enrollment remaining as final membership was slightly below the four-year average for two of the years, and slightly over that average for the other two years.

Although the study was designed to predict the performance only of those without previous chemistry, the population analysis included a determination of the relative numbers of those with and those without previous chemistry instruction. Whereas, in 1954 and 1955, the distribution was only slightly in favor of those with previous instruction in chemistry, by 1957 this figure had increased until there were approximately three out of every five of the final membership who had previously studied this subject.

Although the literature contains adverse arguments there is a preponderance of evidence that the study of chemistry prior to college enrollment is advantageous to those who continue its study in college. This advantage is apparently in evidence at Oklahoma State University, at least during the four years of the study, for 94.0 per cent of those who had taken high school chemistry passed the course as compared with 86.6 per cent of those who had no previous experience in chemistry. When the null hypothesis is invoked, the difference between the two percentages estimates is found to be adequate to reject it at the .01

Essentially identical performance in chemistry was registered by those whose test scores on one or more of the admission tests were not on record as by those whose test scores were complete. The assumption was made and sustained that the lack of certain test scores did not bias the results when this portion of the population was excluded from the final sample.

The selection of the population meeting the criteria yielded two sub-groups: one, numbering 565, from the 1954-1956 classes, and the other numbering 180 from the 1957 class. The first sub-group (565) was obtained from 2,236 who enrolled during the three fall semesters being considered. Of these, 2,043 received a final numerical grade in Chemistry 114, and 943 of these were classified as freshmen at the time and had not previously studied chemistry. When the final criterion of having all admission test scores on record was imposed, the final sub-sample numbering 565 was obtained. Similarly, 758 initially enrolled in this course in the fall of 1957, and 718 of these received a final numerical mark. Two hundred ninety-two of these were of freshman classification at the time and had not previously studied chemistry. Many of these had one or more test scores lacking, and the final sub-sample from this source numbered 180 cases.

Data for the first sub-group (565) yielded correlation coefficients which estimated the relationships that existed between chemistry grades and each of the test scores, and the relationship of each test score to the other test scores. The results were previously reported in Table XV. Three of the correlation coefficients, those between (1) the Q-score and the English score, (2) the chemistry grade and the English score, and (3) the chemistry grade and the Q-score, were found to be in the range 0.30 to 0.39. These are low but are presumed to indicate that correlation is present but that it is slight. Two of the coefficients, English score versus algebra score, and chemistry grade versus L-score, are in the 0.40 to 0.49 range. These are reasonably high, and usually this range is considered a reasonable, and probably significant, relationship. The other five correlation coefficients, namely, (1) Q-score and L-score, (2) L-score and algebra score, (3) L-score and English score, (4) chemistry grade and algebra score, and (5) Q-score anc algebra score, are in the range 0.50 to 0.60. These are substantial relationships, and higher are seldom found because of complicating factors and uncertain measures.[1]

The correlation coefficients were found to be significantly higher for the other sub-groups, the 180 cases from the 1957 class. Whereas only five of the ten correlation coefficients for the previous group were in the 0.50 to 0.60 range, nine of the ten in this series were in this range, or were higher. Actually, four of the ten were in 0.60 to 0.70 range, which is considered the range indicating high significance.

The findings are complicated by the fact that during three of the four years of the study the American Council on Education Psychological Examination was administered at matriculation, while the School and College Ability Test was the examination that was used with the 1957 class, and continues to be administered to entering students prior to admission to the university. A measure of continuity, however, is

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[1]Henry E. Garrett, Statistics in Psychology and Education, (4th ed.; New York: Longmans, Green and Co., 1953), p. 173.

contributed by the fact that the same English examination and the same algebra test were given throughout the four years of the study and continues to be used, although primarily for the purpose of sectioning students in these two subjects, and not as a basis for admission or rejection. Although the English score did not prove significant for predictive purposes for those planning the study of chemistry, the algebra score correlates very significantly with the first-semester chemistry grade (r was 0.58 for the 1954-1956 classes, and 0.63 for the 1957 class). The algebra test score should thus be a substantial factor in advising a student to attempt or to develop the study of chemistry.

The factors leading to the change from the Psychological Examination to the School and College Ability Test can only be surmised, but the linguistic score furnished by either of the two tests proved highly significant in the prediction equations. The correlation coefficient between this score and the chemistry grade was 0.48 for the 1954-1956 classes, and 0.53 for the 1957 class. The correlation was also high between the linguistic score and the algebra score, 0.60 and 0.68, respectively for the two populations.

When the significance of the quantitative score in predicting chemistry grades is examined, the correlation between the Q-score on the Psychological Examination and the chemistry grades achieved was only 0.38, while the equivalent score on the College Ability Test correlated highly with the chemistry grade, an $\underline{r}$ of 0.64 having been obtained. Since the Psychological Examination is no longer being used at Oklahoma State University, this apparent anomaly was not investigated. This finding should prove of more interest to authors of achievement tests and to the Tests and Measurement Bureau than to the person counseling in the field of chemistry.

The multiple coefficients of correlation were quite large, 0.62, when the combined action of the two independent variables--linguistic score and algebra score--on the chemistry grade is calculated in the case of the 1954-1956 classes, and 0.73 when the effect of the three independent variables--quantitative score, linguistic score, and algebra score--on the chemistry grade of the 1957 class is examined. These R's estimate the correlation to be expected between actual grades made in chemistry and grades that would be predicted from the scores used. The use of the prediction equations that have been derived is dependent, however, upon the degree to which future samples (students enrolled in chemistry) are representative of the characteristics of the sample from which these prediction equations were derived.

The regression equation, based on grades made by the 1954-1956 classes, and scores made on the linguistic section of the 1948 American Council on Education Psychological Examination, together with scores made on the Cooperative Elementary Algebra Test, Revised Form Z, is:

$$Y = X_1' = 63.89 + .1406\ X_3 + .2779\ X_5 \qquad (4)$$

To predict Y (or X_1'), which is the chemistry grade likely to be achieved when X_3, the linguistic score on the Psychological Examination, and X_5, the score on the Elementary Algebra Test, are known, the respective coefficients, .1406 and .2779, are multiplied by the respective scores, giving two quantities, which are then added to the constant, 63.89. Where a considerable listing of names and scores has preceded, as will be the usual case, this may conveniently be done by means of a calculator, or, if this is lacking, by means of a slide rule. The use of this equation may be illustrated by using hypothetical scores near the means, and predicting a grade to be expected from such scores, which likewise would be near the mean achieved by the three classes, 1954-1956, from which the data was obtained. If the linguistic score were 57, and the algebra score, 26, the following is obtained:

$$(.1406 \text{ X } 57) + (.2779 \text{ X } 26) + (63.89) = X_1' \tag{8}$$

Multiplying and rounding off gives:

$$7.3 + 8.0 + 63.9 = 79.2$$

Since the standard error of estimate was found to be the $\pm$ 6.2, over two times out of three a person with these particular scores would make a grade in the course that would not be below 73 (above the minimum passing grade), and not above 85 (the minimum for a B grade).

Since the Psychological Examination is no longer being used at Oklahoma State University, predictions using scores on this test would not be of interest except as an illustration of what might be possible from comparable scores on a similar set of tests or at institutions where these tests are still being used.

For immediate use, the equation which best predicts the probable chemistry grade that would be achieved by a beginning chemistry student of freshman classification at Oklahoma State University, who has had no previous instruction in chemistry is:

$$Y = X_1' = .2139\ X_2 + .1507\ X_3 + .1881\ X_5 - 36.17$$

where X_2 and X_3 are the Q- and V-scores, respectively, on the College Ability Test, and X_5, the score on the Elementary Algebra Test, both of which tests have been referred to previously. The constant, 36.17, is subtracted from the sum of the three scores after adjustment to the weight which they have been shown to possess. To illustrate, as before, by using scores near the means achieved by the 1957 class, and predicting a grade to be expected from such scores--which likewise would be near the mean achieved by this class from which data was obtained--the following hypothetical case is offered. If the quantitative score were 304, the linguistic or verbal score were 290, and the algebra score were 25, the following is obtained:

$$X_1' = (.2139 \text{ X } 304) + (.1507 \text{ X } 290) + (.1881 \text{ X } 25) - 36.17.$$

Multiplying and rounding off gives:

$$65.0 + 43.7 + 4.7 - 36.2 = 77.2$$

Since the standard error of estimate was found to be $\pm$ 6.2, a person with these particular scores, over two times out of three would make a grade in the course that would not be below 71.0 (above the minimum passing grade), and not above 83.4 (just under the minimum for a B grade).

For less exact prediction than is possible by substituting scores in the prediction equation, and solving for a numerical grade Table XXV is offered for use. This table shows the means of the three test scores that proved significant in estimating chemistry grades for each of the five letter-grade designations corresponding to the college scale.

TABLE XXV

MEANS OF TEST SCORES ASSOCIATED WITH MEAN NUMERICAL GRADE IN FIVE LETTER-GRADE CATEGORIES

GRADE		MEANS OF TEST SCORES		
Mean Numerical	Letter Equivalent	Quantitative	Verbal	Algebra
94.5	A	320.2	308.0	40.6
88.2	B	316.6	302.6	37.1
80.2	C	308.2	291.4	25.5
72.9	D	298.6	285.7	20.8
65.1	F	291.3	281.0	16.0

The user by simple visual comparison of the test scores of an individual to the means outlined in the table can get a quick approximation for advisement purposes.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

This study has been concerned with the selection of a population for study, and with designing a procedure to determine if a relationship exists between marks students composing this population received in Chemistry 114 at Oklahoma State University and the scores they made on achievement tests prior to matriculation. The procedure for the population analysis included an investigation of (1) the attrition rate in this course, (2) the relative numbers of those with and those without previous chemistry instruction, (3) the possibility of an advantage having been conferred by previous study of chemistry, and (4) whether the lack of test-score data in the case of certain individuals introduced a factor which might bias the relationship being investigated. Two sub-groups were selected, the criteria being the same for both with one exception, the separation into two groups being made necessary by a change in the psychological examination administered at matriculation during one of the years of the study.

Data for the two sub-groups was analyzed in the same manner. Correlation coefficients between each of four admission-test scores and the chemistry grade were computed. A regression equation was calculated for use in predicting the probable grade of future chemistry students who met the same criteria as the test population. The regression coefficients were converted into beta weights in order to determine the relative effectiveness of the various scores used in the prediction equation. Finally, the multiple correlation coefficient involving the significant independent variables was determined in order to see what proportion of the chemistry grade might be accounted for by the variables which had been employed.

Conclusions

This study has demonstrated the usefulness of psychological tests in assessing the scholastic potential of a student considering enrollment in introductory chemistry.

Previous instruction in chemistry at the secondary school level apparently confers an advantage on those who enroll in Chemistry 114 at Oklahoma State University. The benefits are obvious from the data, but how much of the advantage stems from retained subject matter, and how much from background material, attitudes, and motor and vocabulary skills can only be surmised.

The number of students enrolling in Chemistry 114 without previous instruction in chemistry is apparently decreasing, the decrease during the four years being from approximately 47 per cent to 41 per cent of the initial enrollment. No figures were available to indicate how many would have elected high school chemistry had it been offered in the secondary school which these students attended, and it would have been interesting to determine the relative number who failed to elect the course when it could just as well have been taken. Nevertheless, the fact remains that approximately two out of every five enroll in Chemistry 114 at the present time without benefit of having had a high school course in the subject.

The grades made in the introductory course in chemistry by those who have had no previous instruction in the subject is significantly related to the general mathematical ability and the verbal abilities measured by the psychological examination, and to the proficiency in algebra as indicated by the test score in that subject. The contribution to the chemistry grade of the quantitative score on the College Ability Test was greater than either the linguistic section score of the same test or the algebra test score. These three factors together account for 52 per cent of the chemistry grade ($R^2 = 0.52$). The remainder must be accounted for by factors which are not now being measured.

Recommendations

The admission tests which are currently being used at Oklahoma State University admittedly do not account for all factors contributing to chemistry grades. Expansion of this battery of tests might be desirable. Although the English test being used at the present time may fulfill the needs of the English Department, scores on it did not prove significant in predicting chemistry grades. An auxiliary English test that is heavily loaded with verbal comprehension and reading skill factors might be included for purposes of the Chemistry Department.

A future study for the cross validation of the regression equation developed in this study might be made. The investigator might obtain the admission test scores for an incoming class in Chemistry 114 and predict the most probable grade that would likely be made by the use of the regression equation in its present form. If, at the end of the semester, the actual grades that were received were obtained, and the degree of correlation between achieved and predicted grades were calculated, the procedure should yield an estimate of the effectiveness of the regression equation in a sample which was not included in the development of the regression equation.

The predictions possible by means of the regression equation at the present stage of development are not intended to eliminate the need for trained counselors, for the mechanical interpretation possible is just one source of information which contributes to the preview of the performance to be expected in one field of the multiple offerings that are presented by a vast educational institution. In terms of group prediction, however, the regression equation can certainly make a contribution to the attempts of Oklahoma State University to adjust its students to its academic program.

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APPENDIX

CALCULATION OF THE MULTIPLE COEFFICIENT OF CORRELATION

1954-56

$$\beta_{13.5} = \frac{\sigma 3}{\sigma 1} \quad b_3 = \frac{(13.9)\ (0.14)}{(7.8)} = 0.249$$

$$\beta_{15.3} = \frac{\sigma 5}{\sigma 1} \quad b_5 = \frac{(12.7)\ (0.28)}{(7.8)} = 0.449$$

$$R^2_{1.35} = \beta_{13.5}\, r_{13} + \beta_{15.3}\, r_{15}$$

$$R^2_{1.35} = (0.249)\ (0.48) + (0.449)\ (0.58) = 0.119 + 0.260$$

$$R^2_{1.35} = 0.379$$

$$R_{1.35} = 0.615$$

1957

$$\beta_{12.35} = \frac{\sigma 2}{\sigma 1} \quad b_2 = \frac{(15.06)\ (0.214)}{(8.97)} = 0.353$$

$$\beta_{13.25} = \frac{\sigma 3}{\sigma 1} \quad b_3 = \frac{(15.07)\ (0.151)}{(8.97)} = 0.252$$

$$\beta_{15.23} = \frac{\sigma 5}{\sigma 1} \quad b_5 = \frac{(12.32)\ (0.188)}{(8.97)} = 0.260$$

$$R^2_{1.235} = \beta_{12.35}\, r_{12} + \beta_{13.25}\, r_{13} + \beta_{15.23}\, r_{15}$$

$$R^2_{1.235} = (.353)\ (.64) + (.252)\ (.53) + (.260)\ (.63)$$

$$R^2_{1.235} = 0.226 + 0.134 + 0.164 = 0.523$$

$$R_{1.235} = 0.73$$

VITA

Elbert Lloyd Griffin

Candidate for the Degree of

Doctor of Education

Thesis: RELATIONSHIPS BETWEEN FRESHMAN TEST SCORES AND GRADES IN FIRST SEMESTER GENERAL CHEMISTRY

Major Field: Chemical Education

Biographical:

Personal Data: Born at Whitehouse, Smith County, Texas, September 5, 1907, the son of Burton A. and Vera Hagan Griffin.

Education: Attended grade school at Elmo, and Athens, Texas; graduated from Athens High School in 1924; received the Bachelor of Arts degree from Stephen F. Austin State College, Nacogdoches, Texas, with a double major in Chemistry and Education, in June, 1928; received the Master of Arts degree from the University of Texas, with a major in Education, in August, 1947; attended three and one-half summer sessions at the University of Colorado; completed requirements for the Doctor of Education degree in August, 1959.

Professional Experience: Taught high school science at Henderson, Texas, in 1928-29; taught high school science at Marlin, Texas, from 1929-1947, and, in addition, was High School Principal during the last five years of tenure there; taught College Chemistry at Stephen F. Austin State College since 1947, with the exception of the regular sessions in 1956-57 and 1957-58 was absent-on-leave to attend Oklahoma State University; member of the American Chemical Society, Phi Delta Kappa, Phi Lamda Upsilon, and Alpha Chi.