FACTORS IN A STUDENT'S CUMULATIVE SCHOLASTIC RECORD WHICH PREDICT ACHIEVEMENT IN A FIRST COURSE IN COLLEGE PHYSICS

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PREFACE

There appear to be numerous factors in the academic background of students which influence their achievement in college. A great many studies have been made to indentify these factors and determine their relative weights. Many of these studies have dealt with general college achievement. Some have been conducted which dealt with success in particular college courses. Very few studies have been conducted to determine those factors influencing success in college physics.

The purpose of this study was to investigate relationships between achievement in a beginning course in college physics and the available aspects of the student's academic background at the time he enrolled in Physics 114. High school transcripts, standardized test scores, and the grade point averages of all previous college work made up this academic background. A comparison of zero-order correlation coefficients between achievement in these factors and final grades in Physics 114 indicated that the college cumulative average was the best single predictor of success in college physics.

Indebtedness is acknowledged to Dr. Harry K. Brobst, chairman of the advisory committee, for his supervision, guidance, and assistance in this research; and to Dr. H. E. Sorenson and Dr. H. E. Harrington for their interest and encouragement. The author is grateful to Dr. Harrington and his staff for relinquishing class time in Physics 114 in order that certain test data might be acquired concerning the sample.

Indebtedness is also acknowledged to Dr. Wayne Johnson for making available the Cooperative Algebra Test scores and answer sheets. The cooperation of Mr. Raymond Girod and the staff of the Registrar's office in furnishing the high school records of the sample was most valuable to this investigation.

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CHAPTER I

INTRODUCTION

Nature of the Problem

The per cent of students electing physics in the high schools of the United States has decreased steadily during the past sixty years. In 1895 twenty-three per cent of all high school students were enrolled in a course in physics and over ninety-five per cent of those graduating in that year had taken physics. By 1952 there were only four and three tenths per cent of the high school students enrolled in physics and approximately twenty-one per cent of those graduating in that year had studied physics. Thus, high school physics has declined in the same period that has seen physics rise to new importance in our national life. Traditional high school mathematics has also had its difficulties. Percentage-wise enrollment in algebra and geometry has declined to about half of that in 1895. The significance of this trend is of major concern to college physics departments for the per cent of those high school graduates entering college who elect to take a course in physics has also shown a similar trend.

A one-year sequence in college physics is generally considered to be an important foundation course for students majoring in many fields of study. Most engineering students elect a course designated as physics for engineers. Physics majors may start physics in this course. It may also be required of chemistry majors. In many other fields of study a slightly less intensive approach to the study of physics is used. Physics 114 is the first semester of such a course sequence at Oklahoma State University. Yet, a disturbingly large number of those students enrolled in this course failed to achieve a satisfactory standing. Since this group does possess a wide and divergent scholastic background, generally deficient in mathematics, the relative values of those factors in their background that influence their achievement in physics are not immediately apparent. Yet, it seems logical to assume that many such factors are involved in their scholastic background. Most of these factors are a part of the student's academic record. Can achievement in a first course in a physics sequence be predicted from information available in the student's record?

Purpose of the Study

Numerous studies have been made to ascertain those factors which contribute toward success in college. Some studies have been pursued dealing with success in particular college courses. In very few cases have studies been conducted regarding success in college physics. If proper articulation were realized, one would expect to find some relationship between high school achievement and college physics grades.

The specific purposes of this study are: (1) to study relationships between the achievement in a beginning course in college physics and various factors in the high school backgrounds of the students; (2) to study relationships between achievement in a beginning course in college physics and certain aspects of the student's college records at the time of enrollment in physics, (3) to ascertain, from scores on tests administered prior to enrollment in physics, which standard tests have value in predicting success in a first course in college physics.

Importance of the Study

It is expected that by 1970 our system of higher education may have to provide for a doubling of enrollment. Since plans being made by educational institutions account for less than 70 per cent of this total enrollment increase that is forecast, students can expect a higher required academic standing to remain in college. Neither facilities nor staff will be available to provide the student an opportunity to try his hand at this or that. Failure to meet the necessary requirements for any one major may deny even the sincere student the right to try for a second. Yet college records indicate that each year students face this situation in which a change of major becomes necessary.

Some of these failures undoubtedly stem from the inability of some students to accept the conditions of college. However, one can be reasonably certain that the greater number of such situations come about through improper guidance or no guidance at all. All too many students choose a life career because of its popular appeal. They start toward a career about which they know nothing. And many of them are equally uninformed as to their capabilities in this field.

It is generally not possible to predict the achievement of a single individual in a given situation. A student's motivation or will to learn is an important factor in a physics class or any other class for that matter. However, if certain basic relationships between a student's academic record at the time of his initial enrollment in a first course in physics and probable success in that course can be determined, a basis for prediction will have been established.

In the author's own department at East Tennessee State College in a recent year, 105 students registered for a first course in physics. Of this group 39 either failed on the first quarter's work or withdrew during this quarter. Many of these 39 found themselves unable to comprehend physics. For these this meant a revision in their vocational plans. It has also meant that the college had expended facilities in an attempt to teach them a subject they failed to learn.

The importance of this study then becomes twofold. Interpretations of the results of such studies become the basis of an advisement program. Proper evaluation of a student's probable success in any endeavor is important to that student. From the standpoint of the advantageous use of its facilities, this becomes important to the college also.

Statement of the Problem

A review of the literature reveals that many studies have been made in the attempt to ascertain those factors in a student's cumulative scholastic record which contribute toward success in college. There have been a limited number of studies pertaining to success in a particular college course. In very few instances has work been done regarding success in college physics. A blanket statement of inadequate high school preparation is too broad to be meaningful. There must be some relationship between certain aspects of high school and college achievement where proper articulation has been realized. The purpose of this study is an attempt to ascertain those factors in a student's cumulative scholastic record from which one might predict achievement in a first course in college physics.

The specific purposes of this study were; (1) to study relationships between college physics achievement and the achievement in various subject matter fields in high school backgrounds; (2) to study relationships between success in college physics and various aspects of the college records; and (3) to determine if a regression equation involving both high school background and various aspects of the college records could be developed such that prediction by regression in a specific course, college physics, was sufficiently accurate to justify its use.

Delimitations of the Study

The group in this study was delimited to those students who completed Physics 114 at Oklahoma State University during the first semester of the school year 1956-57. The group was further delimited to those students whose high school transcripts or a summary of the transcripts were on file in the Registrar's office at the University. Since those students who had attained graduate standing were not considered as representative of the population, they were not included in the study. Students with a foreign educational background were also excluded since there seemed to be no common basis for evaluating their transferred records.

High school and college marks were used as measures of achievement, with numerical standings converted to letter marks according to the conversion scale indicated by the individual high schools. Since many high schools did not indicate percentile rank in graduating class on transcripts, high school averages were calculated for each of the students and these averages were used as indicators of total high school achievement. High school averages for any subject matter field were not used in calculating correlation coefficients between that field and achievement in Physics 114 unless the student had had two or more years of work in that field.

Sources of Data

This study was delimited to those students who completed Physics 114 at Oklahoma State University during the first semester of the school year 1956-57. The class rolls of the seven sections of Physics 114 for that semester made up the group. The American Council on Education Psychological Examination (ACE)[1] test scores, obtained at the time the students entered Oklahoma State University, were taken from the records of the Bureau of Tests and Measurements, Oklahoma State University. Achievement marks on the Cooperative Algebra Test (Coop-Alg)[2] were obtained from records and filed answer sheets in the Department of Mathematics.

All high school marks were secured from transcripts or a summary of transcripts on file in the Registrar's office of the University. Official records of the Deans of the various Colleges of the University were the sources of college achievement for the group. Since it was deemed advisable to expand the test background of this group, the Pre-Engineering Ability Test (Pre-Eng)[3] and form CM of the Kuder Preference Record (Kuder)[4] were administered to the group in the early part of the semester. In not all cases was it possible to secure complete test data on each of the students enrolled in Physics 114.

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[1]Published by the Cooperative Test Division of Educational Testing Service of Princeton, New Jersey. L. L. and T. G. Thurstone were responsible for the research in the preparation of earlier editions.

[2]This is one of the American Council on Education Cooperative Tests. It is published by the Cooperative Test Division of Educational Testing Service, Princeton, New Jersey.

[3]The Pre-Engineering Ability Test is described in the manual published by the Educational Testing Service, Princeton, New Jersey.

[4]The Kuder Preference Record was developed by Frederic Kuder who is presently Professor of Psychology at Duke University. The test is published by Science Research Associates, Chicago, Illinois.

Treatment of Data

Names of those students who appeared on the class rolls of the seven sections of Physics 114 for the first semester of 1956-57, the initial group of this study, were transcribed to mimeographed data cards. To these cards information of a general nature was added as: age, sex, classification, school, major subject, and high school attended. Each card was checked against the record files of the Bureau of Tests and Measurements and the test records in the Department of Mathematics. From these records the following test scores were recorded:

1. Both parts of the American Council on Education Psychological Examination;
2. Total score on the American Council on Education Psychological Examination; and
3. Marks on the Cooperative Algebra Test.

To this list of tests were added the results of the Pre-Engineering Ability Test and the Kuder Preference Record.

In addition to the final grade in Physics 114 all grades in college mathematics and college chemistry, taken previous to or concurrent with Physics 114, were recorded on the data cards. A notation was also made of both the college cumulative average and the current semester average.

Mimeographed forms were prepared to which individual high school student records were transcribed from the transcripts on file in the Registrar's office. After eliminating fine arts and physical education grades, this information was used to calculate the high school grade average of the individual students of the group. All mathematics, English, and science grades from these mimeographed forms were transferred to the data cards. The letter grade achieved in each subject was quantified by assigning a value of 4 points to A, 3 points to B, 2 points to C, 1 point to D, and 0 to F. This is the grade point system in use at Oklahoma State University. It is also used by many other colleges and universities throughout the United States.

CHAPTER II

SUMMARY OF RELATED LITERATURE

Studies dealing with college achievement vary widely in methods, situations, and conclusions. It would be impracticable to summarize all of the research which has been done regarding college achievement. However, a great many of these studies seem to embody similar research patterns and it is usually possible to observe certain findings recurring in most of them.

This literature survey has been limited to a few fairly representative studies in the broad field of college achievement. To achieve a systematic approach, studies have been considered in the following categories: literature summaries of college achievement; studies of general college achievement; studies of college achievement in mathematics and sciences other than physics; and studies of achievement in college physics.

Literature Summaries of College Achievement. Moore[1] has made a summary of objective studies, completed during the previous ten years, that dealt with the prediction of success in engineering schools. In this summary he has considered correlation coefficients between grade point averages for first term of engineering school and the following predictive items: High school science average; high school mathematics

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[1]Joseph F. Moore, "A Decade of Attempts to Predict Success in Engineering Schools," Occupations, XXVIII (November, 1949), 92-96.

average; high school grade point average in all subjects; various college entrance tests, and total college marks.

These coefficients of correlation varied from a high of .87 for the first semester marks at the University of California to a low of .13 for the Strong Engineering Key at the University of Wisconsin. Considerable spread was also observed in the coefficients of correlation between high school averages and college achievement. At the University of Washington the high school mathematics average correlated .49 with college achievement. While at the University of Minnesota correlation between total high school credits in mathematics, science, and manual training dropped to .19.

Although this summary indicated that mathematics continues to be one of the best means of predicting scholastic success in engineering, Moore feels that the general effectiveness of such prediction instruments has not improved during the period of this study. To this end he suggests that a program of research is needed to develop and improve measuring devices for exploring such factors as industriousness, initiative, imagination, and persistence. The inference here is that many instruments of prediction lose part of their effectiveness when students with adequate mental ability fail to complete college.

Segel[2] has made a summary of studies on prediction of success in college. Although the report is some twenty-five years old, it is by far the most comprehensive compilation found in present literature. He found that the mean coefficient of correlation between general college scholarship and achievement on the American Council on Education

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[2]David Segel, "Prediction of Success in College," United States Office of Education Bulletin 1934, Number 15 (Washington: United States Government Printing Office, 1934), pp. 19-71.

Psychological Examination was .39 with a low of .27. Only one study relating this test to achievement in college physics was cited. The value of r found was .55. It is interesting to note that results of the Iowa Physics Aptitude Placement Test, included in this report, showed a correlation coefficient of .50 and .40 with achievement in college physics. Prediction of achievement in college chemistry varied from a coefficient of correlation of .59 to .28 depending upon the tests employed. Correlations in mathematics showed approximately the same range of values.

Segel found that, in general, the predictive value of any instrument decreased with each additional semester of college work. From a summarization of the data on correlation coefficients he concludes that general achievement tests at the end of the high school course are more prognostic of general college scholarship than general mental tests. This summarization also shows that prediction correlation coefficients using average high school marks are more variable than coefficients obtained through the use of general scholastic aptitude or general achievement tests.

Travers[3] takes a rather cynical view of the more than 1,000 studies of tests, for the purpose of predicting some aspect of scholastic achievement, that have appeared in the previous fifteen years. He makes three main points of his analysis.

His first criticism of many published studies is that they represent repetitions of studies previously carried out by numerous investigators. He also feels that many of these studies are based on the belief that

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[3]Robert M. W. Travers, "The Prediction of Achievement," School and Society, LXX (November, 1949), 293-94.

the main reason for the inadequacies of present predictions is that tests previously have not been properly designed to measure adequately those factors which make for success. Travers questions this assumption that the individual's own characteristics, as measured by tests, are entirely responsible for his success or failure. A third consideration is the common assumption that, in assigning grades, teachers are all trying to measure some kind of common denominator. However, some teachers assign grades on the basis of final status. Others assign final grades on the basis of a student's growth.

In 1942 Emme[4] reviewed 44 studies dealing with prediction of college success. He discussed seven criteria for the prediction of college success and concluded that the data of these 44 studies revealed that, of the seven criteria, rank in a high school graduating class or high school performance seemed to be the best single criterion for predicting college success. One study included in the report indicates that subcorrelations from high school records are better predictors for "A" and "B" students than for those with "C" and below. Another study from the University of Michigan indicates that students from small high schools are less likely to survive in college than those from larger schools.

Emme cited the study of Leaf[5] who developed two regression equations by which he could predict the average college marks of approximately 66 per cent of the students within .44 and .40 of a letter mark. He felt

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[4]Earle E. Emme, "Predicting College Success," Journal of Higher Education, XIII (May, 1942), 263-67.

[5]Curtis T. Leaf, "Prediction of College Marks," Journal of Experimental Education, VIII (March, 1940), 303-07.

that this method was probably the best of those reviewed. Emme emphasized the importance of interest and enjoyment of college work.

Studies of General College Achievement. Numerous individual studies relating general achievement in high school with that in the first college work have been published. Most of these studies have found high school achievement to have definite predictive value for general college achievement. Some studies have shown it to be more valuable than freshman test batteries.

Buckton and Doppelt[6] studied the results of the battery of tests used at Brooklyn College for admission purposes during the previous ten years. They found that the correlation between the criterion of freshman index (an average based on the course work of the freshman year) and the battery score was .41; between freshman index and high school average the correlation was .63; and between freshman index and final rating, .63. From this they concluded that a much better prediction of the freshman index may be made from high school average than from a test battery score. Ashmore[7] has also found that high school marks were very significant in predicting college success.

Several other studies have produced noteworthy results. Lauer and Evans[8] studied a random sample of 492 students of an entering class of 1800. They also found that high school average was slightly superior

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[6]La Verne Buckton and Jerome E. Doppelt, "The Use of Selection Tests at Brooklyn College," Occupations, XXVIII (March, 1950), 357-60.

[7]Ben Ashmore, "High School Teachers' Marks as Indicators of College Success," Journal of the American Association of Collegiate Registrars, XXI (January, 1946), 219-30.

[8]Alvhh R. Lauer and J. E. Evans, "The Relative Predictive Value of Different High School Subjects on College Grades," School and Society, XXXI (February, 1930), 159-60.

to intelligence test records for prediction on first quarter grades. However, other data they obtained indicated that as the student advanced in college the correlation with high school grades decreased but the correlation with intelligence increased.

Gough[9] made a study investigating non-intellectual factors in predicting scholastic achievement. To this end he constructed a test of some 200 true and false items. The answers to these questions were judged to be indicative of personalogical areas pertinent to scholastic achievement. This test was then administered to the senior students in four Minnesota high schools. In each of the four schools the correlation between this test and achievement was above .5. Gough feels that high scores on the test were suggestive of greater seriousness of purpose, more persistence in academic and scholastic pursuits, and more diligent and systematic work habits.

Treumann and Sullivan[10] at the University of Wisconsin administered a battery of tests which included the American Council on Education Psychological Examination, the Iowa Silent Reading Examination and the Engineering and Physical Science Aptitude Test to 240 entering engineering students. The authors state that this group was of superior scholastic aptitude, of inferior reading ability, and of superior engineering aptitude.

At the end of the fall semester scholastic achievement was correlated with these tests. For this group the Engineering and Physical

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[9]Harrison G. Gough, "What Determines the Academic Achievement of High School Students," Journal of Educational Research, XLVI (January, 1953), 321-31.

[10]Mildred Jenkins Treumann and Ben A. Sullivan, "Use of the Engineering and Physical Science Aptitude Test as a Predictor of Academic Achievement of Freshman Engineering Students," Journal of Educational Research, XLIII (October, 1949), 129-37.

Science Aptitude Test was the best single predictor of academic success though it was very closely approached by high school percentile rank. Both parts of the American Council on Education Psychological Examination and the Iowa Silent Reading Test ranked low in predictive ability.

Hurd[11] felt that the great varieties of abilities of students involved was responsible for the absence of more significant correlation between test scores and achievement records. He strongly recommended that prediction tests intended for prediction alone should be of the same type and in the same field as the achievement which is being predicted. Smith[12] found that coefficients of correlation in certain fields of high school and first semester college work centered around .50 with a number below this figure. He found that the best single indicator, of those studies, of scholastic success in any given semester is the previous semester's record. Previous high school records and entrance examination records, he felt, seem to begin to lose their value to a slight degree after a lapse of time of a year or more.

In a comparative study of 15 large Michigan high schools, Dressel[13] found that grades represented wide variations of achievement in the different schools even though the 15 were a fairly homogeneous group of schools. He suggested that the results indicated that predictions of college grades could be somewhat improved by a knowledge of these differences.

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[11] A. W. Hurd, "The Problem of the Prediction of College Success," Journal of Educational Research, XXXVIII (November, 1944), 217-19.

[12] Francis F. Smith, "Use of Previous Records in Estimating College Success," Journal of Educational Psychology, XXXVI (March, 1945), 167-76.

[13] Paul L. Dressel, "The Effect of the High School on College Grades," Journal of Educational Psychology, XXX (November, 1939), 612-17.

Entering freshmen at Southwest Texas State Teachers College were given the following tests: American Council Psychological Examination; Cooperative English Examination; and Use of Library Materials Test. From this data Votaw[14] developed a regression equation. He found that in this combination of test scores, used to predict the subsequent success of entering college freshmen, the Library scores contributed the greatest weight.

These three studies are worthy of note because of the remarkably high coefficients they obtained. Edds and McCall[15] found that high school averages best predicted college marks in science and least adequately predicted mathematical ability. Their regression equation showed that high school records should be weighed twice as much as intelligence test records and ten times as much as English results. They used only 85 cases in a small college and admitted that their college grades ran abnormally high.

A coefficient of correlation of .64 between high school averages and first semester college marks was found by Schmitz[16] to be higher than that for any other prognostic factors that he investigated. Since he also worked with a comparatively few students from a small denominational college, it might be inferred here also that their

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[14]David F. Votaw, "A Comparison of Test Scores of Entering College Freshmen as Instruments for Predicting Subsequent Scholarship," Journal of Educational Research, XL (November, 1946), 215-18.

[15]Jesse H. Edds and W. Morrison McCall, "Predicting the Scholastic Success of College Freshmen," Journal of Educational Research, XXVII (October, 1933), 127-30.

[16]Sylvester B. Schmitz, "Predicting Success in College: A Study of Various Criteria," Journal of Educational Psychology, XXVIII (September, 1937), 465-73.

grading standards conformed closely to those of the high schools from which their students came.

An even higher coefficient of correlation, .77, between high school averages and college freshmen marks was obtained by Finch and Nemzek[17]. However, Finch and Nemzek worked with only 118 graduates from the University of Minnesota Laboratory School who entered the University. It is to be expected that articulation in this case would be somewhat easier, resulting in a high coefficient of correlation.

In an attempt to test the accuracy of the statement that "students coming from larger high schools, regardless of their rank in class, achieve better grades in college than do students from the small high schools who are in the upper thirty percent of their class," Altman[18] studied the records of 144 graduating seniors from Central Michigan College. On the basis of this study she concluded that graduates of the larger high schools did not achieve significantly higher point averages than did the graduates of the smaller schools. She also found rank in the upper ten per cent of the high school class was a better predictor of college achievement than rank below the tenth percentile.

Swenson[19] studied 300 entering students at the University of Pittsburgh. He concluded that students from the higher two-fifths of their

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[17]F. H. Finch and C. L. Nemzek, "Prediction of College Achievement from Data Collected During Secondary School Period," Journal of Applied Psychology, XVIII (March, 1934), 454-60.

[18]Ester Royal Altman, "The Effect of Rank in Class and Size of High School on the Academic Achievement of Central Michigan College Senior Class of 1957," Journal of Educational Research, LII (April, 1959), 307-09.

[19]Clifford H. Swensen, Jr., "College Performance of Students with High and Low High School Grades when Academic Aptitude is Controlled," Journal of Educational Research, L (April, 1957), 597-603.

high school graduating classes appeared to obtain higher quality point averages in college than those from the lowest three-fifths, and that for a given American Council on Education Psychological Examination score, a student from the highest two-fifths would probably obtain a higher quality point average than one from the lowest three-fifths of his graduating class.

Studies of College Achievement in Mathematics and Sciences other than Physics. Most studies already reviewed have dealt with general achievement at the college level with reference to high school grades or test scores on standardized college entrance examinations. There are some few studies that have dealt with achievement in particular curricula.

One of these studies was made by Miles[20], who investigated the predictive value of high school and college records in the arts and sciences curriculum at Louisiana State University. Many of his coefficients of correlation were in the vicinity of .60. These values seem rather unusual in the light of other literature reviewed. However, it must be remembered that he was dealing with general achievement rather than achievement in a single course. He agreed with many others that rank in high school class was probably one of the best predictors of achievement in college.

Bowers[21] studied freshmen engineering students at Oklahoma State University to select optimal predictors of success in the first semester

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[20]Ray W. Miles, "Prediction of Achievement in the College of Arts and Sciences from Data Obtained from High School and College Records" (unpublished Master's thesis, Louisiana State University, Baton Rouge, 1948), p. 62.

[21]Royal Huleh Bowers, "The Selection of the Optimal Predictors of Success in the First Semester of the Engineering Program of the Oklahoma Institute of Technology" (unpublished Doctor's dissertation, Oklahoma State University, Stillwater, 1956), p. 41.

of their engineering program. For one group of 343 first year students, he found a correlation coefficient of .58 between the scores on the Pre-Engineering Ability Test and their grade point averages. This same coefficient was also obtained between the Cooperative Algebra Test and their grade point averages. Scores on other standardized entrance tests showed a somewhat lower correlation with college achievement. It is interesting to note that Bowers found that these two tests were also among the best predictors of mathematics and chemistry grades.

While there have been some few studies carried out in the field of chemistry in an effort to determine prediction factors, most of these studies seem to exhibit no consistent conclusions. Wakeman[22] studied the relationship between certain high school subjects and achievement in a first course in college chemistry. From his study he concluded that a course in high school chemistry was beneficial to a student in beginning college chemistry. However, he found that most of the 107 high schools he studied gave students higher chemistry grades than they made in college chemistry.

Oakley[23], dealing primarily with the test scores rather than with letter grades, concluded that high school chemistry was a significant help in college chemistry. Hoff[24] also found that those students who had a unit of high school chemistry had a very slight advantage in college chemistry.

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[22]G. Wakeman, "High School Subjects and General College Chemistry," School and Society, XLI (June, 1935), 739-40.

[23]W. J. Oakley, "A Study of the Relationship Between Certain Factors and Achievement in College Freshman Chemistry" (unpublished Master's thesis, Louisiana State University, Baton Rouge, 1939), pp. 58-59.

[24]Arthur G. Hoff, "The Effect of the Study of High School Chemistry Upon Success in College Chemistry," Journal of Educational Research, XL (March, 1947), 539-42.

Williams and Lafferty[25] sought to determine if those students in freshmen college chemistry at East Texas State Teachers College who had taken a course in high school chemistry enjoyed any advantage over those who had had no previous course in chemistry. Groups used for this two-year study were students classified as freshmen at one time during the years 1948 to 1950. The population was 171 students about equally divided between those with a course in high school chemistry and those without.

The authors used as a basis of judgement the differences between the averages of the two groups. This differential, calculated at the end of every three weeks period, showed considerable positive fluctuation. This fluctuation, the authors felt, showed a correlation between those topics studied in high school chemistry and those in college chemistry. The final examination differential was only plus 4. This indicated that those students with high school chemistry had a small but distinct advantage over those who had not. However, there was no attempt made to evaluate the success in college chemistry in the light of the academic achievement in high school.

Hoff[26] studied the grades achieved by 340 freshmen students in chemistry at State Teachers College, La Crosse, Wisconsin. Of these, 92 students had not studied chemistry in high school and 254 had. He found that the high school chemistry group showed a slightly superior scholastic ability over the not-high school chemistry group. When the

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[25]Byron Williams and H. M. Lafferty, "High School Chemistry -- Asset or Liability in College," Journal of Educational Research, XLVI (November, 1952), 207-17.

[26]Arthur G. Hoff, pp. 539-42.

abilities of the two groups were equalized, the students who had studied chemistry in high school maintained a grade point factor advantage of only .83 per cent. The author concluded that because of this extremely low grade point factor advantage the study of chemistry in high school had no significant effect on the grades achieved in college chemistry. Had Williams and Lafferty[27] considered the relative academic standing of their two groups they might have found an even smaller advantage of high school chemistry to students taking freshmen college chemistry.

Merle E. Betts[28] investigated the effectiveness of high school chemistry in predicting the probability of success in beginning college chemistry for students taking a course in vocational agriculture at Iowa State College. The immediate object of the study was to prepare probability tables which would show just how many chances in 100 a given student of agriculture would have of successfully completing the beginning chemistry course at Iowa State College. The published table was an integration of two tables. In the first, high school average was tabulated against the American Council on Education Psychological Examination percentile rank for those students with high school chemistry. In the second table the same factors were tabulated for those students without a course in high school chemistry. While no correlations were given, it appeared that the results would indicate a high correlation between high school average and probability of successfully completing a first course in college chemistry. In each case calculated, a given high school average indicated a slightly higher probable achievement for those students who had had high school chemistry.

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[27]Byron Williams and H. M. Lafferty, pp. 207-17.

[28]Merle E. Betts, "High School Chemistry for College Preparation," The American Agricultural Education Magazine, XXV (April, 1953), 223-24.

Chemistry is a field which is closely related to physics. Another related field is that of mathematics, a field in which a great many studies have been conducted in achievement. Because of the mathematical nature of most physics, several of these studies will be reviewed in more detail than some of those previously discussed. Two independent studies in the middle thirties found a high correlation between high school and college mathematics. These were studies of Douglas and Michaelson[29] and Garrett[30] who found a coefficient just below .50 between high school mathematics averages and freshmen mathematics achievement. On the contrary, Hanna[31] found a correlation coefficient between high school mathematics average and freshman mathematics average of only .32.

Bromely and Carter[32] investigated the predictability of success in mathematics at the Gales Division of the University of Illinois. The criterion selected for success was the average grades earned in college mathematics. This criterion was correlated with the results of seven standardized entrance tests. Of particular interest to the report were the coefficients of correlation between the average grades in college mathematics and a few selected variates as follows: total score on the Cooperative General Achievement Test, r = .35; total score on the

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[29]Harl R. Douglas and Jessie H. Michaelson, "The Relations of High School Mathematics to College Marks and of Other Factors to College Marks in Mathematics," School Review, XLIV (October, 1936), 615-19.

[30]H. L. Garrett, "Predicting College Success Upon the Basis of Senior High School Records," Peabody Journal of Education, XI (March, 1934), 193-201.

[31]Joseph V. Hanna, "A Comparison of Cooperative Test Scores and High School Grades as Measures for Predicting Achievement in College," Journal of Applied Psychology, XXIII (April, 1939), 289-97.

[32]Ann Bromley and Gerald C. Carter, "Predictability of Success in Mathematics," Journal of Educational Research, XLIV (October, 1950), 148.

American Council on Education Psychological Examination, r = .24; Mathematics Comprehension and Interpretation score on Cooperative General Achievement, r = .32; and rank in high school class, r = .40.

Two parts of this study were rather significant to the nature of our problem. The highest coefficient of correlation occurs between the criterion of proficiency in college mathematics, that is the average mathematics grades, and rank in the high school graduating class. A second point of interest is the fact that, of the regression coefficients showing relative weights of these measures in contributing success in mathematics, rank in high school graduating class was by far the largest.

Seigle[33] conducted a study at Washburn Municipal University to find some of the factors that were predictive of success in college mathematics at Washburn. He also wanted to find the relative prognostic value of the Washburn Entrance Mathematics Test, the high school grade average, and the number of units of high school mathematics submitted. The population for the study was all the students enrolled in the mathematics department in the years 1946 to 1949 inclusive, accounting for 1205 students. Coefficients of correlation between the scores of each of the prognostic factors and the grades in college algebra were computed. The authors concluded that the Washburn Entrance Mathematics Test was the best single predictor of success in college algebra that was found in this study. The high school grade average was the second best predictor of success in college mathematics if the prediction was made before any college mathematics had been taken. They found that the amount of high school mathematics taken by the student seemed to play a very small part

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[33]William F. Seigle, "Prediction of Success in College Mathematics at Washburn University," Journal of Educational Research, XLVII (April, 1954), 577-88.

in his success in other mathematics courses after his first course in college mathematics.

Studies of Achievement in College Physics. There seem to have been fewer studies conducted in physics achievement in college than in either mathematics or any of the other sciences. Several investigations have been concerned with the value of high school physics to those enrolled in college physics. Three early investigations are of interest. Hurd[34] found college physics achievement slightly superior for those who had had a course in high school physics. A small difference was also found by Rudy[35] favoring those with high school physics. Ham[36], using a coefficient of correlation of .30, concluded that, "The common statement that high school physics has no value for those taking college physics is not confirmed."

The importance of mathematical ability in studying college physics was a point emphasized in the study of Stuit and Lapp[37]. In their study they found a coefficient of correlation of .65 between college physics and scores on the Iowa Mathematical Aptitude Test. This led to the conclusion that mathematics ability appeared to be more closely related than any other factor to achievement in college physics.

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[34]A. W. Hurd, "High School Physics Makes Small Contribution to College Physics," School and Society, XXXI (April, 1930), 468-70.

[35]James Earl Rudy, "A Study of the Grades of the West Virginia University First Year Physics Students with Reference to Previous Training in High School Physics," Science Education, XXV (April, 1941), 210-13.

[36]L. B. Ham, "High School Physics as a Preparation for College Physics," American Physics Teacher, IV (September, 1936), 190-94.

[37]D. B. Stuit and C. L. Lapp, "Some Factors in Physics Achievement at the College Level," Journal of Experimental Education, IX (March, 1941), 251-53.

Foster[38] obtained a rather high coefficient of correlation, .74, between high school physics and college physics. Since Foster used an admittedly small group, there is some doubt that the group for his study was a true sample of the student population.

One of the most comprehensive studies in recent years on achievement in college physics is that of Kruglak and Keller[39] at the University of Minnesota. This was a study to determine whether achievement in the sophomore engineering physics course sequence could be predicted from information available in the student's record. The sample population was restricted to male students taking sophomore physics who were regularly enrolled in the Institute of Technology, having a minimum of 15 credit hours in mathematics, 13 hours in chemistry and giving a home address somewhere in continental U.S.A. This gave a sample population of 343. The achievement criteria were the final grades in the three quarters of physics and the scores on the several Cooperative Physics Tests.

Grades for the final quarter of the physics sequence for this study gave the following Pearson coefficients of correlation: with American Council on Education Psychological Examination total scores, $\underline{r}$ = .24; with Cooperative Algebra Test scores, $\underline{r}$ = .14; with freshman mathematics point-hour ratios, $\underline{r}$ = .51; with freshman total honor point ratio, $\underline{r}$ = .57. The correlation coefficient between the final quarter of the physics sequence and high school rank was only .17. The authors offered as an

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[38]C. A. Foster, "The Correlation of the Marks in Certain High School Subjects with those in College Chemistry and Physics," School Science and Mathematics, XXXVIII (October, 1938), 743-46.

[39]Haym Kruglak and Robert J. Keller, "The Prediction of Achievement in Sophomore Engineering Physics at the University of Minnesota," American Journal of Physics, XVIII (March, 1950), 140-46.

explanation for this low correlation the fact that the sample was mostly veterans who were somewhat removed from high school.

In this review of the literature an attempt has been made to sample from the studies conducted over the past thirty years. No clear-cut pattern has been found. In fact the findings have been rather diverse. Yet, a few general trends can be recognized. In almost all cases where the relation between college achievement and success in a particular college course was studied a high coefficient of correlation was found. Thus indicating that a student who has done well in college has a high probability of succeeding in any particular course.

Even though Dressel[40] found that high school grades represent a wide variation of achievement in different school systems, high school rank seems to have some value as a predictor of college success.

Many of the studies reviewed have investigated the value of various standardized entrance tests as predictors of college success. With few exceptions, scores on those tests of a general nature have not shown a high correlation with achievement in college physical sciences and mathematics. Tests such as the Pre-Engineering and Physical Science Aptitude Test have shown much more promise in these fields. This concurs with the feeling of Hurd[41] who strongly recommended that prediction tests intended for prediction alone should be in the same general field as the achievement which is being predicted.

Correlation coefficients of courses in high school physical sciences and mathematics with achievement in college physics have not been high.

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[40]Paul L. Dressel, pp. 612-17.

[41]A. W. Hurd, pp. 217-19.

A majority of the investigators have indicated a slight advantage in college physics or chemistry for those who have had a high school course in that subject. However, there is also some indication that those students who elect college physics or chemistry, who have had a corresponding course in high school, have ranked higher in their high school achievement than those without the corresponding course.

A study of high school physics texts would indicate that during the last quarter-century the material of these books has become highly descriptive. While high school physics texts and college physics texts cover much the same material, physics concepts in college are approached through mathematics. The lack of mathematics in high school physics texts is consistent with the relaxed emphasis on mathematics in high school. This trend has been quite disturbing to such organizations as The American Association of Physics Teachers. The Physical Science Study Committee is a result of this concern. New and more intensive courses in high school physics are being developed. When this is accomplished a higher articulation between the two levels of physics should be expected.

CHAPTER III

POPULATION, INSTRUMENTS AND PROCEDURES

In the first part of this chapter the criteria used in the selection of a sample population are listed. This is followed by an analysis of the results of the application of these criteria to the total enrollment in Physics 114 in the fall semester of 1956. All of the tests used as independent variables are described and the statistical design of the study discussed.

The Sample Population

The sample population of this study was obtained by applying certain selection criteria to the total enrollment in Physics 114 during the fall semester of 1956 at Oklahoma State University. A statistical problem of this nature requires that the sample population be measured in all of the independent variables. Students enrolled in Physics 114 come from several different colleges of the University. While there are minimum requirements established by the Physics Department for enrollment in Physics 114, it can not be expected that educational backgrounds of all of these students will be equivalent.

In order to restrict this investigation to a more homogeneous sample, the following criteria were set up to select the sample population in which a student's record was eliminated from the sample if it failed to satisfy one or more of the following conditions:

(1) Enrollment as a regular undergraduate student in Physics 114 at Oklahoma State University during the first semester of the school year 1956-57.

(2) A complete high school transcript or summary of transcript on file in the Registrar's office of the University.

(3) Secondary education acquired somewhere in the continental United States.

(4) Scores recorded on the following standardized tests: American Council on Education Psychological Examination, Cooperative Algebra Test, The Kuder Preference Record, and The Pre-Engineering Ability Test.

Criterion (1) excluded graduate students from the study. Criterion (3) eliminated students with a foreign educational background. The fourth criterion eliminated those students who had managed to evade taking the standardized entrance tests.

Students enrolled in the seven sections of Physics 114 for the first semester of 1956-57, the initial group of this study, totaled 237. Table I shows an analysis of this group. One hundred fifty-six, or approximately two thirds of this group satisfied the above criteria.

TABLE I

ANALYSIS OF THE INITIAL GROUP OF THIS STUDY

Classification of Group	Number
Total Number of Students Enrolled in Physics 114	237
Undergraduate Students Whose Records were Incomplete	59
Graduate Students	12
Students Who Withdrew from Course	10
Sample Population	156

Of those undergraduate students whose records were incomplete, 31 had no high school transcript or summary of transcript on file in the Registrar's office. Only two of this number graduated from a high school outside the United States.

Tests Used in this Study

Since the first year of physics is generally taken after the freshman year, most of the students enrolled in Physics 114 had met the entrance testing requirements. This meant that the scores on both parts of the American Council on Education Psychological Examination and the Cooperative Algebra Test were already a part of their record. Through the cooperation of the Bureau of Tests and Measurements of the Oklahoma State University, form ZPA of the Pre-Engineering Ability Test and form CM of the Kuder Preference Record were administered to the seven sections of Physics 114 soon after the first of the semester. This gave a battery of four tests to be used as independent variables. A description of each of these tests follows:

1. American Council on Education Psychological Examination (ACE).[1] This test was designed to measure linguistic and quantitative factors of intelligence. It is normally administered in the freshman year and is used as an indication of the ability of college freshmen to do satisfactory work in their first year at college. The test consists of two parts: Linguistic (L), and Quantitative (Q). The linguistic score provided a measure of the student's vocabulary knowledge and ability to reason with words, that is, verbal facility. The quantitative section

[1]A test published by the Cooperative Test Division of Educational Testing Service of Princeton, New Jersey.

of the test was designed to measure the ability to understand and reason with quantitative concepts. Scores for each of these two parts of the test may be combined for a total score which was used in most instances in this study. It is generally a part of the test battery given incoming freshmen at many colleges and universities. Most of the literature reviewed in which testing was involved included a summary of these scores.

2. Cooperative Algebra Test, Form Z (Coop-Alg.).[2] The Cooperative Algebra Test was designed to measure the general proficiency in the field of elementary algebra. This test has usually been included among those tests given to incoming freshmen since most students are expected to have acquired these basic skills in high school mathematics. For a number of years the Department of Mathematics at Oklahoma State University has used the scores on this test, together with data from the high school records, to determine the proper sections of mathematics for freshmen.

3. Pre-Engineering Ability Test, Form ZPA (Pre-Eng.).[3] The Pre-Engineering Ability Test, an 80-minute test, is designed to have wide application in predicting scholastic success in first-year engineering programs of study. It is expected that the test will be used with graduating high school seniors or incoming college freshmen. This test replaces the Pre-Engineering Inventory (six-hour Long Form and four-hour Short Form). Most of the test questions for the Pre-Engineering Ability Test have been selected from those in the Pre-Engineering Inventory.

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[2]The Cooperative Algebra Test, as previously referred to, is one of the American Council on Education Cooperative Tests. It is published by the Cooperative Test Division of Educational Testing Service.

[3]The Pre-Engineering Ability Test is described in a manual referred to in a previous footnote. It is published by the Educational Testing Service, Princeton, New Jersey.

This test has two separately timed parts so that each student will have an opportunity to work on both parts. Part I has 45 items dealing with the comprehension of scientific materials and is limited to 45 minutes. Part II, the general mathematical ability section, has 40 items and a 35 minute limit. It measures the ability to apply the principles of arithmetic and algebra in reasoning out the solutions to specific problems. The authors consider the total test more nearly an aptitude than achievement test.

The reliability coefficient is estimated at .90 by means of the Kuder-Richardson Formula 20 for a group of 305 engineering freshmen at an eastern engineering college. The authors state that the items in the Pre-Engineering Ability Test were a carefully selected half of the most internally consistent items in part III - Comprehension of Scientific Materials and part IV - General Mathematical Ability. Lord, Cowles, and Cynamon[4] found the median validity of the Pre-Engineering Inventory composite scores against first term averages to be .60. On the basis of this data, they estimated the validity of parts III and IV combined scores to be .58. This gives an indication of the validity of the Pre-Engineering Ability Test.

4. The Kuder Preference Record, Form CM (Kuder).[5] The Kuder Preference Record is used to predict educational and vocational success. Development of the Record-Vocational began in 1934. Form A was published in

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[4]F. Lord, J. T. Cowles, and M. Cynamon, "The Pre-Engineering Inventory as a predictor of success in Engineering College," Journal of Applied Psychology, XXXIV, No. 1 (February, 1950).

[5]The development of the Kuder Preference Record is referred to in a previous footnote. The test is published by Science Research Associates, Chicago, Illinois.

1939 and included seven interest areas. In 1948 Form C was made available. This form was designed to measure the motivating factors in ten broad areas. These areas include measurement of interest of the outdoor, mechanical, computational, scientific, persuasive, artistic, literary, musical, social service, and clerical. A "V" scale is included to detect inconsistencies in the student's answers.

Reliability coefficients were computed by the method developed by Kuder and Richardson using 100 high school boys and 100 high school girls. These coefficients ranged from a high of .93 on the mechanical scale for boys to a low of .84 on the musical scale for girls.

The specific use of the Kuder Preference Record - Vocational in a student counseling program is that of pointing out occupations that involve the type of duties for which the student expressed preferences. It should be understood that the Preference Record is not intended to substitute for measures of ability.

CHAPTER IV

THE HIGH SCHOOL BACKGROUND OF THE SAMPLE

The purpose in this chapter is to evaluate the achievement of the sample in the various high school fields. To make this evaluation meaningful it was necessary to place certain limitations on the data. In arriving at the total average achievement of each student in high school, it was felt that only those phases of his course work that required considerable mental activity should be included. Thus such courses as driver education, physical education and glee club were not considered. On the other hand, those fields which provide the basic skills for calculation and communication were singled out for more detailed study.

Subject groupings used by other investigators were followed except where it seemed advantageous to do otherwise. Unless the student had taken two or more years in a field, such as science or mathematics, his marks in that field were not used in calculating the average achievement of the sample in that field.

<u>Achievement of Sample in Secondary Science</u>. Since physics and chemistry are the two high school science subjects of most interest to this study, the achievement in each of these was determined separately. In studying the achievement of this sample in their total secondary science program, semester grades in general science, agriculture,

biology, chemistry, geology, and physics were used, provided the student had taken a minimum of two years of science. The averages of students having less than two years of science were not used.

Table II presents an analysis of the achievement, as judged by the marks received, of the sample in their secondary science program.

TABLE II

ACHIEVEMENT OF SAMPLE IN HIGH SCHOOL SCIENCE

Course	Number	Per Cent	Mean Grade	Sigma
Physics	53	33.97	2.481	.926
Chemistry	76	48.71	2.664	.908
Total Science	108	69.23	2.682	.719

This table shows that 108 or 69.23 per cent of the sample had two or more years of science in high school. Chemistry was elected by 76 or better than 48 per cent of the sample, while physics interested only 53 or approximately 34 per cent. The mean achievement of the group with two or more years of science was 2.682 which was slightly better than the average grades in either chemistry or physics. The fact that the total science average included general science and agriculture, subjects generally considered to require less rigorous thinking, might account for this better achievement.

A mean semester mark of 2.481 for physics was an interesting aspect of this analysis. This is appreciably lower than either the science average or the chemistry average. It was also found that the mean secondary achievement of the 53 taking high school physics was 2.839 as compared to a mean of 2.741 for those of the sample not taking physics in high school. It seems reasonable to conclude that the high school physics courses were more difficult than courses in the other sciences. This same conclusion could have been based on opinions of high school instructors who teach physics and one or more other science courses.

It is interesting to note that 48 or 31 per cent of this sample had less than two years of science in high school. However, the mean achievement of these 48 in Physics 114 was 2.041. This was slightly better than the mean grade of the entire sample. Even though the sample was small, their achievement in Physics 114 would seem to have indicated that two years of high school science was not a criterion for success in college physics.

Achievement of the Sample in High School English. Although Edds and McCall[1], in developing their regression equation, found that high school averages should be weighed ten times as much as English scores, there is some evidence to indicate that high school English was meaningful in predicting success in college. Basic skills in communication, as acquired in courses in high school English, should be a major tool for studying any college field.

Even though there seems to have been some variation among high schools as to the years of English required, all of the sample had taken two or more years of English. Table III shows that over 80 per cent or 125 had taken through English IV. In some cases students had elected to substitute Business English which was not used in this study. There was also some evidence that students elected to take literature rather than grammar where permitted.

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[1] Jesse H. Edds and W. Morris McCall, pp. 127-30.

TABLE III

ACHIEVEMENT OF SAMPLE IN HIGH SCHOOL ENGLISH

Course	Number	Per Cent	Mean Grade	Sigma
English IV	125	80.12	2.616	.872
English Average	156	100.00	2.668	.671

The mean mark in English IV was among the lowest of the achievement in any of the high school fields included in this study. A total English average of 2.668 was only slightly better. Although Algebra II is considered one of the more difficult subjects in high school, it is of interest to note that the average achievement in Algebra II was .055 higher than English IV. Algebra II is generally an elective in high school, while English IV may have been required in most cases. It is not feasible to determine the number of high schools represented that required four years of English. Algebra II as an elective would be taken by those students who felt a need and an interest in the subject.

Achievement of the Sample in High School Mathematics. As has been previously pointed out, Physics 114 carries as a prerequisite a working knowledge of algebra and geometry. This is indicative of a marked tendency in the entire field of physics toward a more quantitative approach. In fact, the student who chooses to major in physics will find that he has also worked out almost a major in mathematics as well. Hence, one would expect to find achievement of the sample in high school mathematics important to this study.

The generally accepted sequence in high school mathematics is: First Year Algebra, Plane Geometry and Algebra II. The larger high schools may also offer Solid Geometry and Trigonometry to seniors.

TABLE IV

DISTRIBUTION OF MATHEMATICS COURSES TAKEN BY SAMPLE IN HIGH SCHOOL

General Math.	Algebra I	Algebra II	Plane Geometry	Trig.	Solid Geometry
51	151	78	119	25	20

Table IV shows number of individuals in the sample submitting credit in each of the high school mathematics courses. It is interesting to note that all but five of the sample had taken Algebra I. These five had taken general mathematics and plane geometry. Almost all of the 25 students who took trigonometry in high school also took solid geometry. There were seven students, not shown in Table IV, who took either advanced algebra, college geometry or advanced arithmetic.

TABLE V

ACHIEVEMENT OF SAMPLE OF 156 IN HIGH SCHOOL MATHEMATICS

Course	Number	Per Cent	Mean Grade	Sigma
Algebra II	76	48.71	2.671	.962
Mathematics Av.	141	90.38	2.669	.836

In order to summarize the sample's achievement in high school mathematics, the semester averages in this field were calculated. All of the courses listed in Table IV were used to arrive at a mathematics average for 141 students. The averages of those who did not have a minimum of two years of high school mathematics were not used. Since a working knowledge of algebra was a prerequisite for Physics 114, the achievement in Algebra II was also investigated. This result, along with the mathematics average, is shown in Table V. Average achievement in Algebra II was only slightly better than the mathematics average. The closeness of these two means was an indication of a high consistency in high school mathematics. Yet either was somewhat lower than the mean average achievement, 2.781, of the sample in all high school subjects.

Achievement of the Sample in all High School Subjects. Several studies that were reviewed have considered the student's rank in high school class important as a predictive criteria. To be sure this is certainly one measure of a student's overall high school achievement. However, high school transcripts for most of the sample did not indicate rank in graduating class. Since these transcripts did indicate marks in all subjects for each student of the sample, it was possible to compute the high school average for each student. Lauer and Evans[2] had found this average slightly superior to intelligence test records in predicting first quarter grades. Table VI gives the mean and standard deviation of the total high school achievement of the sample.

TABLE VI

ACHIEVEMENT OF THE SAMPLE IN ALL HIGH SCHOOL SUBJECTS

Course	Number	Per Cent	Mean Grade	Sigma
High School Av.	156	100	2.781	.609

If a grade of "C" is the mean high school achievement, then the mean grade of the sample, 2.781, indicated that this sample ranked better than the average high school graduate. One would expect the

[2]Alvhh R. Lauer and J. E. Evans, pp. 159-60.

achievement in high school to be somewhat of an indication of the desire to go to college. It should also be remembered that most of this sample had also been selected through one or more years of college prior to taking Physics 114. It is not surprising then to find that the mean high school achievement of the sample to be somewhat higher than the average high school class. The value of sigma found here is less than for the other groupings. This would indicate more bunching of the grades about the mean.

CHAPTER V

ACHIEVEMENT IN CERTAIN ASPECTS OF COLLEGE WORK

Achievement in College Physics. The subject matter of Physics 114 is mechanics, heat, and sound. It is described in the Bulletin of Oklahoma State University as a beginning course in general physics for non-engineering students. The course carries a prerequisite of a working knowledge of algebra and geometry. Physics 114 and Physics 124, a beginning course in light and electricity, are a requirement for curricula in several of the colleges of the University.

Of the 237 students enrolled in the seven sections of Physics 114 in the fall of 1956, 215 received a final grade. Table VII shows the distribution of the total marks in terms of the number of cases and the per cent of the total number of cases. This table shows a mean semester mark of 1.953, which would be an average of slightly less than "C". Using a standard deviation of 1.262 and assuming a normal distribution, approximately 68 per cent of the marks would fall in the range .691 to 3.215. A study of this distribution shows that it is far from a normal distribution. If one wishes to classify a group into five sub-groups of "A" to "F" according to ability, the range of ability to be equal in each group, he would find 45 per cent of the group should receive a grade of "C". This distribution shows approximately 30 per cent receiving a grade of "C", while better than three times the percentage of a normal distribution received grades of "A" or "F". This departure from the normal distribution was probably attributable to several factors: (1) the group was not large enough to expect a close approximation to a normal distribution, (2) each instructor made out his own tests and assigned marks, and (3) specific vocational plans probably furnished a varying motivation for a large majority of these students.

TABLE VII

DISTRIBUTION OF SEMESTER MARKS IN BEGINNING PHYSICS
FOR SAMPLE OF 215 STUDENTS

Semester Marks	Number	Per Cent	Mean	Sigma
A	26	12.09		
B	51	23.72		
C	64	29.76	1.953	1.262
D	34	15.81		
F	40	18.60		

Fifty-nine of the 215 undergraduates completing the course did not have records complete in all of the independent variables. This resulted in a sample population of 156 students receiving a final grade in Physics 114 who had scores recorded on all of the factors considered in this study. Table VIII shows the distribution of semester marks in Physics 114 for this group. With a mean of 1.980 and a standard deviation of 1.248 this distribution seems only slightly closer to a normal distribution than did the group of 215. This mean of 1.980 for 65.80 per cent of the original registrants compares favorably with 2.0 for 33.90 per cent of the original population of the study of Kruglak and Keller[1].

[1]Haym Kruglak and Robert J. Keller, p. 142.

TABLE VIII

DISTRIBUTION OF SEMESTER MARKS IN BEGINNING PHYSICS
FOR SAMPLE 156 STUDENTS

Semester Mark	Number	Per Cent	Mean	Sigma
A	20	12.82		
B	37	23.72		
C	45	28.84	1.980	1.248
D	28	17.94		
F	26	16.66		

To insure that in selecting the sample population of 156 from the group of 215 the characteristics of the population as to achievement in Physics 114 had not changed, the significance of the difference between the means of the two groups was checked. Calculations were based on a method of pooled variance. The results of these calculations are shown in Table IX.

TABLE IX

SIGNIFICANCE OF DIFFERENCE BETWEEN MEANS
FOR SAMPLES OF 215 AND 156 STUDENTS

Difference Between Means	t-values	df (pooled)	P
.027	.111	369	not significant

From a table of t values, the probability of a larger value of t for 369 degrees of freedom is much greater than 0.5. An hypothesis that there was no significant difference between these two means was accepted.

In reviewing the literature a number of studies were found in which an attempt was made to compare college achievement between groups who lacked specific high school training in a particular field with those who had such training. High school physics is one of those fields. In this sample, 53 or 34 per cent of the sample had taken a course in high school physics. Table X shows the results of this comparison.

TABLE X

ACHIEVEMENT IN COLLEGE PHYSICS OF THOSE STUDENTS WHO HAD TAKEN HIGH SCHOOL PHYSICS AND THOSE WHO HAD NOT

Students With High School Physics					Students Without High School Physics				
Mark	Number	Per Cent	Mean	Sigma	Mark	Number	Per Cent	Mean	Sigma
A	8	15.09			A	13	12.62		
B	14	26.41			B	23	22.33		
C	15	28.30	2.113	1.269	C	29	28.15	1.912	1.267
D	8	15.09			D	20	19.41		
F	8	15.09			F	18	17.40		

Insofar as the distribution of college marks was concerned, the most notable difference between these two groups was that 41.50 per cent of the group who had taken high school physics received a grade of "A" or "B" in Physics 114. Only 36 per cent of the group without high school physics scored in the same bracket. The significance of the difference between the mean-achievement in Physics 114 for those students who had taken high school physics and those without high school physics was checked as shown in Table XI.

TABLE XI

SIGNIFICANCE OF DIFFERENCE BETWEEN MEAN-ACHIEVEMENT IN PHYSICS 114 FOR THOSE WITH AND WITHOUT HIGH SCHOOL PHYSICS

Difference Between Means	t-values	df (pooled)	P
.201	.939	154	not significant

For 154 degrees of freedom one would expect to find a value of t as large as 0.939 in approximately 35 out of 100 samples. This indicated that there was no significant difference between these two means.

When the achievement in all high school subjects of those of the sample who had taken high school physics was compared with the achievement of those who did not take high school physics, those taking high school physics were found to have a slightly higher grade point average. The 53 who took high school physics had a mean of 2.839. The mean achievement of the 103 who did not take high school physics was 2.740 However, there was no significant difference between these means.

Chemistry is a subject that is more often offered in high school than physics. For this reason it might be expected that a number of those taking Physics 114 whould have had a course in high school chemistry. Seventy-six or 48.70 per cent of this sample had taken such a course. Table XII shows the influence of this background on achievement in Physics 114.

TABLE XII

ACHIEVEMENT IN COLLEGE PHYSICS OF THOSE STUDENTS WHO HAD TAKEN HIGH SCHOOL CHEMISTRY AND THOSE WHO HAD NOT

Students With High School Chemistry					Students Without High School Chemistry				
Mark	Number	Per Cent	Mean	Sigma	Mark	Number	Per Cent	Mean	Sigma
A	9	11.84			A	11	13.75		
B	19	25.00			B	18	22.50		
C	24	31.57	2.000	1.256	C	20	25.00	1.963	1.269
D	10	13.15			D	19	23.75		
F	14	18.42			F	12	15.00		

The mean achievement of this group in Physics 114 was 2.000. Achievement for the group without high school chemistry was 1.963. The difference between the two means, .037, was not even sufficient to indicate a possible trend. Such a result might have been expected since high school chemistry is usually quite non-mathematical.

In reviewing the achievement of the sample in Physics 114, several points of interest have been noted. It has been found that the distribution of the semester marks in Physics 114 for this sample departed somewhat from a normal distribution, showing some of the characteristics of a platykurtic curve. Achievement in college physics for that group who had taken a course in high school physics, while slightly better than for those who had not taken high school physics, was not significantly better. In addition, the group with high school physics was found to have a slightly higher high school average than the group without high school physics. The inclusion of chemistry in the high school background did not indicate any advantage to the student in Physics 114.

The apparent lack of substantial subject articulation between high school and college physics has become the concern of many who are associated with college physics instruction. The Physical Science Study Committee was organized in 1956 to devise a modern course in physics for secondary schools and to prepare the materials for such a course. Teacher conferences and achievement test results have been the basis for numerous revisions in this course. To this same end The National Science Foundation has sponsored 20 in-service institutes during the academic year 1960-61 to familiarize teachers with the program.

<u>Achievement in College Mathematics</u>. The extent of the college background in mathematics and the achievement in that background should have some bearing on the achievement in Physics 114. Entering students who take the Cooperative Algebra Test at Oklahoma State University are assigned to mathematics courses on the basis of their scores on this test. On this basis 100 of the sample had started their college mathematics with either intermediate algebra, college algebra or a combination of college algebra and trigonometry. Forty-five had been required to take Mathematics 145 which is beginning and intermediate algebra. Nine, for some reason, had taken no course in mathematics in college. On the other hand, 50 had taken three or more courses.

In calculating the mean achievement in this mathematics background the average mark of each student was used where the student had taken at least one course in college mathematics. Table XIII gives the mean achievement and the standard deviation for the sample in college mathematics.

TABLE XIII

ACHIEVEMENT OF SAMPLE IN COLLEGE MATHEMATICS

Course	Number	Per Cent	Mean Grade	Sigma
College Average	147	94.23	2.104	.994

This mean for college mathematics was 2.104. A mean achievement of 2.669 for high school mathematics would indicate that college mathematics was somewhat more difficult for this group. The fact that 45 were not ready to take college algebra suggests that there were not sufficient courses in their high school mathematics background or that the grading system was much more lenient in high school. In any event, the mean marks in college mathematics would seem to indicate that high school mathematics did not adequately prepare the sample for the normal sequence in college mathematics.

Achievement in College Chemistry. A check in the various Deans' offices showed that 130 of the sample had taken first year college chemistry. Twenty-five of these had continued with one additional advanced course and 13 had taken at least two more courses in chemistry. Table XIV shows the mean and standard deviation of the group. In calculating the mean, each student's average mark was used where that student had taken a minimum of one year of college chemistry. It should be noted

TABLE XIV

ACHIEVEMENT OF SAMPLE IN COLLEGE CHEMISTRY

Course	Number	Per Cent	Mean Grade	Sigma
College Average	130	83.33	2.362	.846

that the mean student achievement in college chemistry for 130 of the sample was 2.362 with a standard deviation of .846. This mean is considerably higher than the mean mark found for Physics 114. It is only very slightly less than the mean college average or cumulative average of the sample at the time they enrolled in Physics 114. It seems logical to conclude that the students of this sample found college chemistry much easier than Physics 114. Since chemistry is far less mathematical than physics, their high school work could have been a better preparation for college chemistry.

The Cumulative Average and Current Average. It is the practice of each college of the University to keep a record of both the average achievement for each semester's work and the mean or cumulative average for all courses taken in college for each student. The cumulative average for each member of the sample, up to the time he enrolled in Physics 114, and the current average or semester average for the semester in which he took Physics 114 were made a part of this study. The mean and standard deviation are shown in Table XV.

TABLE XV

TOTAL ACHIEVEMENT OF SAMPLE IN COLLEGE

Course	Number	Per Cent	Mean Grade	Sigma
Cumulative Average	144	92.30	2.372	.713
Current Average	156	100.00	2.411	.838

The mean of this cumulative average for 144 students of the sample was 2.372 with a standard deviation of .713. Twelve students of the sample had elected to take Physics 114 as freshmen and did not have a cumulative average. This mean of the cumulative averages of the individual students of the sample was somewhat better than the mean achievement in either college mathematics or Physics 114.

The current average or mean of the achievement in all work attempted during the semester in which the students took Physics 114 was found to be 2.411 as compared with the cumulative average of 2.372. This might indicate that the sample's work had improved with tenure in college. The transition from the tightly supervised type of school organization in high school to the freer and more individualistic nature of college life makes the first year of college one of the most difficult for many students.

CHAPTER VI

STANDARDIZED TEST BACKGROUND

Included in the testing program that entering freshmen at Oklahoma State University undergo there were two tests of interest to this study. These were the American Council on Education Psychological Examination and the Cooperative Algebra Test. To give additional background information for this study the Pre-Engineering Ability Test and the Kuder Preference Record were given to those enrolled in Physics 114 soon after the semester started. Table XVI shows the mean, sigma, and the percentile rank of the mean score as given in published norms.

The American Council on Education Psychological Examination is used rather extensively by teachers and counselors both in high schools and colleges. The 1952 edition norms bulletin presents a summary of the scores reported by 269 colleges for 42,332 students. This test was designed to measure linguistic and quantitative factors of intelligence. The linguistic score provided a measure of verbal facility and the quantitative score was designed to test ability to understand and reason with quantitative concepts.

Table XVI indicates a mean linguistic score of 59.467 with a corresponding percentile rank of 41 for men in a four year college. The mean quantitative score of 42 for the sample corresponded to a mean percentile rank of 47. Since these students were majoring in fields requiring a knowledge of physics, it might be expected that the mean percentile rank of the quantitative scores would be higher than those for the linguistic scores. It is surprising that both of these means should fall below the 50 percentile rank on the national norms.

TABLE XVI

STANDARDIZED TEST DATA

Test	Mean	Mean Percentile Rank	Sigma
Linguistic	59.467	41.00	15.243
Quantitative	42.000	47.00	10.877
ACE Total	101.198	42.00	24.710
Cooperative Algebra	25.628	53.67	11.550
Pre-Engineering Ability	39.256	63.75	11.313
Kuder Preference Record			
Outdoor	49.666	52.32	13.031
Mechanical	43.224	38.33	11.917
Computational	27.589	50.94	9.310
Scientific	46.122	72.24	12.386
Persuasive	35.423	42.26	10.151
Artistic	25.506	68.53	10.160
Literary	17.769	51.84	7.662
Musical	10.807	48.64	6.698
Social Service	38.948	37.84	13.493
Clerical	41.397	37.57	9.696

The Cooperative Algebra Test, Form Z, has been used for many years at Oklahoma State University as a basis for determining the type of algebra to which incoming freshmen would be assigned. The mean of the scores of the sample on this test was 25.628 with a standard deviation of 11.550. This gave a mean percentile rank of 53.67 based on a study of the scores of 766 students at Oklahoma State University in September of 1953. In the table of standards used for classifying algebra students, a score of 26 or slightly better than the mean and three semesters of high school algebra were necessary to be permitted to take college algebra. For less than three semesters of high school algebra a score of 38 was required. Only 47 or approximately 30 per cent of this sample had been permitted to start their college mathematics in college algebra. Thirty-two of the sample were required to start mathematics with beginning algebra.

The Pre-Engineering Ability Test grew out of the Pre-Engineering Inventory which, although a most effective predictor of scholastic success in the first year of engineering college, was expensive, long, and difficult to administer. The two parts of the Pre-Engineering Inventory which contribute most to the validity of its composite score became the basis for the Pre-Engineering Ability Test. These were (1) Comprehension of Scientific Materials and (2) General Mathematical Ability. Items that make up the Comprehension of Scientific Materials part of this test require little specific factual knowledge. While a familiarity with the physical science language is useful, it is not essential since such items as charts and tables supply nearly all the information needed. Questions dealing with mathematics require an ability to apply principles of arithmetic and algebra in arriving at the solutions. The reliability of the test is considered to be high enough for use in the selection and guidance of individual students.

Two class periods were used to administer the Pre-Engineering Ability Test to the seven sections of Physics 114 making up the sample. Since only thirty-five minutes were necessary for the second part of the test, the first fifteen minutes of the second period gave sufficient time to re-issue the answer sheets.

As indicated in Table XVI this mean score on the Pre-Engineering Ability Test for this sample was 39.256 with a standard deviation of 11.313. Using the percentile data for 5,144 freshmen enrolled in publicly supported engineering colleges, this mean score gives a mean percentile rank of 63.75. This figure seems rather high for this sample. Although the academic experience of the sample, for the most part, was above that of freshmen, their mathematical and scientific background was definitely not engineering. However, as the calculations of Chapter VII show, the Pre-Engineering Ability Test was among the better predictors of success in Physics 114.

The Kuder Preference Record completed the test background of the sample. Since forty minutes is the maximum time usually required to complete the test, it was given in one period. Two specific uses of the Kuder Preference Record - Vocational in guidance programs are to point out occupations for further study and to verify a person's choice of occupation. While this test is a means of identifying desirable occupations, it is understood that they must be supplemented with measures of ability. The Preference Record is not a measure of ability.

Since most of the students of the sample had already chosen their occupations, it was not intended to use the test as a verification of their choice. Rather, it was thought that there might be some degree of correlation between the scores in one or more of the ten broad occupation areas and the achievement in Physics 114. Information in the Examiner Manual suggests that scores below the 75th percentile lose much of their significance. While the mean percentile rank of 72.244 on the scientific scale was the highest of any of the scales, the correlation between the scores on the scientific scale and the achievement in Physics 114 was disappointing. However, a spot check of the information cards did show a reasonable correlation between chosen occupations and percentile ranks on the corresponding scales.

Very little work has been done on the problem of predicting actual grades by use of the Preference Record. Kendall and Hahn[1] found a small but significant correlation between the scientific scale and grades in a college of medicine. Romney[2] also found a low correlation between the literary scale and freshmen English grades at Brigham Young University.

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[1] William E. Kendall and Melton E. Hahn, "The Use of Tests in the Selection of Medical Students by the College of Medicine of Syracuse University," The American Psychologist, II (June, 1947), 297.

[2] A. Kimball Romney, "The Kuder Literary Scale as Related to Achievement in College English," Journal of Applied Psychology, XXXIV (February, 1950), 40-41.

CHAPTER VII

CORRELATIONS BETWEEN THE VARIOUS PHASES OF THE HIGH SCHOOL AND COLLEGE BACKGROUND

In order to establish the predictive value of each of the independent variables, zero-order correlation coefficients r were determined between achievement in Physics 114 and various aspects of high school and college work. Since it was assumed that this relationship could be considered linear, the correlation between the various achievements was expressed by the product-moment coefficient of correlation.

The significance of an r obtained in the above manner may be tested against a null hypothesis. The method consists in assuming the population r to be zero and comparing the t value for the obtained r with the t's to be expected by chance at the .05 or .01 limits. The t for a given r is found from the formula

$$t = \frac{r\sqrt{N - 2}}{\sqrt{1 - r^2}}$$

in which r is the obtained coefficient and N is the number of cases. A calculated t equal to or larger than a value of t expected by chance at the .05 or .01 limits indicates a corresponding level of confidence. A simpler method of testing the significance of an r is to enter prepared tables with N-2 degrees of freedom and compare the sample r with the tabulated entries. For the 37 students with high school physics and Algebra II a value of r of .325 would be significant at the .05 limit.

Since correlations were to be a very important part of this study, it seemed advisable to present these correlations in three separate tables. The intercorrelations between aspects of the high school records and correlations between these aspects and achievement in Physics 114 are given in Table XVII. In this table one notes that the highest correlation

TABLE XVII

INTERCORRELATIONS BETWEEN HIGH SCHOOL DATA
AND CORRELATIONS WITH PHYSICS 114

	X_3	X_5	X_6	X_8	X_9	X_{11}	X_{12}	Phys.114
X_1 H.S. Av.	.802 (53)*	.728 (76)	.847 (108)	.812 (76)	.834 (141)	.743 (125)	.876 (156)	.206** (156)
X_3 H.S. Phys.		.717 (40)	.859 (53)	.676 (37)	.703 (51)	.764 (47)	.798 (53)	.347** (53)
X_5 H.S. Chem.			.767 (70)	.730 (44)	.620 (72)	.428 (61)	.608 (76)	.202** (76)
X_6 H.S. Sci.				.797 (57)	.779 (100)	.687 (88)	.779 (108)	.230** (108)
X_8 H.S. Alg. II					.897 (76)	.617 (66)	.510 (76)	.231** (76)
X_9 H.S. Math Av.						.580 (110)	.759 (141)	.221** (141)
X_{11} H.S. Eng. IV							.712 (125)	.210** (125)
X_{12} H.S. Eng. Av.								.175** (156)

* Numbers in parentheses refer to students used in calculations
** Significant at the .05 level of confidence

between any of the high school subjects and achievement in Physics 114 was .347 for high school physics. This was significant at the five per cent level of confidence, yet the fact that this value of r was only .347 indicates that subject articulation between high school and college physics was notably poor. As noted previously, there are several groups working independently on this problem. Seeking to gain more retention of subject matter, the emphasis of their approach has been on basic principles and less on techniques and the solution of problems. However, there are those who are quick to point out that achievement in a first course in college physics is generally measured on the ability of the student to solve problems.

The next best predictor of the final grade in Physics 114 in the high school work of the sample was the Algebra II achievement. This value of .231 was only slightly better than .221 for the high school mathematics average. Third in the order of predictors, the science average correlated .230 with Physics 114. The lowest value of $\underline{r}$ found was .175 for the high school English average.

Although the values of the coefficients of correlation obtained for Algebra II and high school mathematics with Physics 114 were low, they were significant at the five per cent level of confidence. The fact that they ranked second and fourth would tend to confirm an emphasis on the mathematical aspects of college physics. Several studies cited have found the element of recency to be significant in establishing predictive criteria. This element of recency may have given Algebra II a slight edge over the high school mathematics average. The former is frequently taken by seniors, whereas the average is based on all mathematics taken in high school.

Since the subject matter of chemistry and physics do have some basic concepts in common, it was surprising to find the coefficient of correlation between high school chemistry and Physics 114 ranking seventh in predictive value. Where students take both chemistry and physics in high school, they normally have had chemistry in the junior year and physics in the senior year. Here the element of recency may have been a factor. Probably of greater significance is the fact that chemistry was offered by both large and small high schools, whereas physics was offered primarily by the larger high schools. Numerous studies have indicated a marked tendency in smaller schools for marks to be higher.

Although the high school science average did rank third as a predictor, the value of $\underline{r}$ was disappointingly low. An explanation of this might be found in the nature of these sciences included in the average. There is a wide difference between biological sciences and physical sciences. The basis for a biological science is living matter, while physical sciences are mostly energy centered. Physical sciences are experimental while biological sciences are mostly observational. One may also expect to find more biological science than physical science in a course in general science. When this and the element of recency are considered, an $\underline{r}$ of .230 is not unreasonable.

As mentioned previously, the lowest value of $\underline{r}$ found in the high school work was that for the high school English average with Physics 114. Since the subject-matter presentation in Physics 114 was mathematical in nature, there was probably little opportunity for using English skills. However, the ability to read and understand is a very necessary skill in the study of physics.

In reviewing numerous studies of general college achievement, it has been found that rank in class has received considerable emphasis. Rank in graduating class was not available for enough of the sample to make a study of the correlation between this and physics achievement meaningful. While high school averages can not be considered synonymous with rank in high school graduating class, they are some indication of rank achieved. The correlation between high school average and achievement in Physics 114 was .206. Although this is significant at the five per cent level of confidence, it is much lower than many of the values of r found in studies on relation of rank in class to college achievement.

Intercorrelation coefficients between high school subjects was found to be quite high. The values of r found ranged from a low of .428 for the correlation between high school chemistry and English IV to a high of .798 for the correlation between high school physics and English IV. There were several other values of r higher than this value cited such as .897 between Algebra II and high school mathematics average. In every case calculated the correlation between a particular subject and high school average was high. This probably indicated that the high school standard of grading, although not as high as the college standard, was quite consistent.

Intercorrelations between the various aspects of college achievement of the population up to the time they enrolled in Physics 114 is shown in Table XVIII. In most cases the entire sample was included in each of the various correlations. Numbers in parentheses below values of r refer to students used in calculation. One observes immediately from this table that most of the aspects of college achievement have far more predictive value relative to achievement in Physics 114 than did high school records.

It will be noted that a correlation coefficient of .446 between the total scores achieved on the Pre-Engineering Ability Test and the

TABLE XVIII

INTERCORRELATIONS - COLLEGE DATA

	Y_2	Y_3	Y_4	Y_5	Y_8	Y_9	Y_{12}	Z_1	Z_2	Z_3	Phys 114
Y_1 Pre-Engineering	.566 (156)*	.530 (156)	.495 (156)	.556 (156)	.255 (156)	.022 (156)	.153 (156)	.471 (144)	.437 (130)	.426 (147)	.446** (156)
Y_2 Cooperative Algebra		.330 (156)	.661 (156)	.484 (156)	.230 (156)	.080 (156)	.209 (156)	.331 (144)	.351 (130)	.359 (147)	.432** (156)
Y_3 ACE Linguistic			.611 (156)	.882 (156)	.209 (156)	.077 (156)	.240 (156)	.331 (144)	.209 (130)	.341 (147)	.265** (156)
Y_4 ACE Quantitative				.919 (156)	.056 (156)	.006 (156)	.208 (156)	.313 (144)	.257 (130)	.337 (147)	.173** (156)
Y_5 ACE Total					.081 (156)	.087 (156)	.215 (156)	.378 (144)	.303 (130)	.379 (147)	.238** (156)
Y_8 Kuder 2 (Computational)						.256 (156)	.065 (156)	.029 (144)	.001 (130)	.169 (147)	.182** (156)
Y_9 Kuder 3 (Scientific)							.001 (156)	.201 (144)	.371 (130)	.249 (147)	.157 (156)
Y_{12} Kuder 6 (Literary)								.068 (144)	.079 (130)	.086 (147)	.242** (156)
Z_1 College Cumulative Average									.714 (129)	.653 (137)	.519** (144)
Z_2 College Chemistry Average										.510 (123)	.408** (130)
Z_3 College Mathematics Average											.490** (147)

*Numbers in parentheses refer to students used in calculations

**Significant at the .05 level of confidence

Physics 114 final grades indicated that this test was the best predictor of achievement in Physics 114 of all of the standardized tests used. A value of r of .432 between the Cooperative Algebra Test and achievement in Physics 114 would indicate that this test is also a good predictor of Physics 114 final grades. It is also another indication of the mathematical nature of Physics 114.

The correlation coefficients between Physics 114 final grades and the various parts of the American Council on Education Psychological Examination were low but significant at the five per cent level of confidence. It is of interest to note that the linguistic part of the test with a value of r of .265 proved to be a better predictor of Physics 114 achievement than did either the quantitative part or the total score. Values of r of .331, 313, and .378 as correlation coefficients between the three scores of the American Council on Education Psychological Examination and the college cumulative average indicated that these scores were better predictors of total college achievement than for Physics 114 final grades. An explanation for this might be found in the fact that, in terms of their respective objectives in college, this was a heterogeneous population. For many of them Physics 114 might have been just another required course.

The Kuder Preference Record - Vocational was given to the sample population in the hope that some correlation might be found between certain areas of interest and achievement in Physics 114. This record measures preference in ten broad areas. It helps make a systematic approach to the problem of an occupation. It is not intended as a measure of ability. Yet ability is assumed to be easier to acquire where there is sufficient interest. Correlation coefficients between the scores in each of these ten areas and final grades in Physics 114 are given in Table XIX.

TABLE XIX

CORRELATION COEFFICIENTS BETWEEN KUDER PREFERENCE RECORD SCALES AND PHYSICS 114 FINAL GRADES

Scale	Mean	Mean Percentile Rank	Sigma	r
Y 0 (Outdoor)	49.66	52.32	13.03	-.135
Y 1 (Mechanical)	43.22	38.33	11.92	-.233
Y 2 (Computational)	27.59	50.95	9.31	.183**
Y 3 (Scientific)	46.12	72.24	12.38	.158**
Y 4 (Persuasive)	35.42	42.27	10.15	-.204
Y 5 (Artistic)	25.51	68.53	10.16	-.238
Y 6 (Literary)	17.77	51.85	7.66	.242**
Y 7 (Musical)	10.81	48.65	6.69	-.071
Y 8 (Social Service)	38.95	37.84	13.49	.094
Y 9 (Clerical)	41.39	37.58	9.69	.079

**Significant at the .05 level of confidence

Five of these areas - Outdoor, Mechanical, Persuasive, Artistic, and Musical - gave negative correlation coefficients with Physics 114 final grades. For Social Service and Clerical, the values of r were not significant at the five per cent level of confidence. This left three of the scales to be included in Table XVIII. Of these scales, the Kuder Literary Scale showed the highest correlation, .242, with Physics 114. The highest intercorrelation between any of the scales and other aspects of the college data was a value of .255 between the

Kuder Computational scale and the Pre-Engineering Ability score. From these values it must be concluded that there was no marked correlation between any of the Kuder Preference Record scales and the achievement in Physics 114.

The college cumulative average, the average of all of the college work attempted prior to enrolling in Physics 114, was by far the best predictor of achievement in Physics 114. A correlation coefficient of .519 for this relation was better than the relation between the Pre-Engineering Ability Test and Physics 114. This is very much in line with what other studies have shown.

A correlation coefficient of .490 between the college mathematics average and Physics 114 indicated that mathematics achievement in college is a good predictor of success in physics. This again is a good indication of the mathematical nature of physics. Correlation between the college chemistry average and achievement in Physics 114 gave a coefficient of .408. While this is not as high a coefficient as for the relation between the college cumulative average and physics achievement, it does indicate that achievement in college chemistry is much more meaningful in predicting success in college physics than was achievement in high school chemistry.

Correlations between the high school averages and various aspects of college achievement are shown in Table XX. These values range from high of .714 between the high school physics average achievement and the college cumulative average to a low of .211 between the average of all of the high school work and the scores on the Pre-Engineering Ability Test. It is of interest to note that this average of all high school work, a relatively poor predictor of achievement in Physics 114, had

TABLE XX

INTERCORRELATIONS - HIGH SCHOOL DATA WITH COLLEGE DATA

	Y_1	Y_2	Y_3	Y_4	Y_5	Z_1	Z_2	Z_3	Phys 114
X_1 H. S. Average	.211 (156)*	.363 (156)	.309 (156)	.490 (156)	.416 (156)	.470 (144)	.538 (130)	.414 (147)	.206** (156)
X_2 H. S. Physics Average	.463 (53)	.543 (53)	.504 (53)	.449 (53)	.570 (53)	.714 (44)	.417 (34)	.446 (50)	.347** (53)
X_6 H. S. Science Average	.460 (108)	.297 (108)	.297 (108)	.334 (108)	.304 (108)	.476 (97)	.676 (86)	.403 (100)	.230** (108)
X_9 H. S. Mathematics Average	.299 (141)	.406 (141)	.228 (141)	.427 (141)	.277 (141)	.415 (129)	.469 (114)	.401 (132)	.221** (141)

Y_1 Pre-Engineering

Y_2 Cooperative Algebra

Y_3 ACE Linguistic

Y_4 ACE Quantitative

Y_5 ACE Total

Z_1 College Cumulative Average

Z_2 College Chemistry Average

Z_3 College Mathematics Average

*Numbers in parentheses refer to students used in calculations

**Significant at the .05 level of confidence one of the lowest coefficients of correlation with the Pre-Engineering Ability Test, one of the best predictors of college physics scores. Yet the Pre-Engineering Ability Test showed good correlation with high school physics and high school science averages. A value of $\underline{r}$ of .543 between high school physics marks and the Cooperative Algebra Test was the highest coefficient obtained between this test and high school averages. Why it should correlate higher with high school physics than with the high school mathematics average is not readily explained.

All three scores on the ACE Psychological Examination seemed to be better indicators of what had been accomplished in high school than predictors of college achievement. While it was to be expected that the quantitative part of this examination would have a higher correlation with the high school mathematics averages than did the linguistic or total scores, it is not so obvious that the total score should show the best correlation of the three with high school physics.

Correlation coefficients between the college cumulative average and high school averages indicated that those students who did good work in college had also done well in high school. As stated previously, the coefficient between high school physics and the college cumulative average was one of the largest values of $\underline{r}$ obtained for correlations between high school work and college achievement. The college chemistry averages also showed good correlation with high school averages.

Correlation coefficients between Physics 114 and high school averages, on the other hand, contrasted very sharply with the values of $\underline{r}$ obtained for other aspects of the college record with high school averages. Values ranged from a low of .175 with high school English to the previously stated high of .347 with high school physics. Results of this comparison of coefficients of correlation seem to indicate that high school averages may be used to predict some aspects of college achievement with more accuracy than the final grades in Physics 114.

CHAPTER VIII

THE REGRESSION EQUATION

During the past fifty years a large number of investigators have concerned themselves with the problem of the relationship between students' marks in college and their background of high school achievement and or scores on various standardized examinations which were administered prior to their entrance into college. The ultimate purpose of these studies has been to find criteria for accurate prediction of the student's achievement in college.

Although, in most every case, these studies have been concerned with general achievement, they have indicated that it is not possible to predict the scholastic achievement of a high per cent of the students in a given group. Many cases of success or failure in college can not be determined until the student has tried to do college work. This determination is even more difficult in the case of a single subject.

Very few studies have been conducted where an attempt has been made to predict the achievement of individual students of a group in a particular subject. Leaf[1] developed a five-variable regression equation to predict the status of a group of 97 freshmen at the

[1] Curtis T. Leaf, pp. 303-07.

time of their entrance into La Salle-Peru-Oglesby Junior College. He used the American Council on Education Psychological Examination score, the Iowa English Aptitude Examination score, the Iowa High School Content Examination score, and the four-year high school average as his independent variables. His criteria were the average college marks for the freshman year. By comparing the predicted average college mark for the freshman year with that actually attained, he determined a standard error of estimate of prediction of .44 of a letter grade. Kruglak and Keller[2], in their study of achievement in a sophomore engineering physics course at the University of Minnesota, calculated multiple correlation coefficients and developed a regression equation. However, in their published work they did not indicate that they had determined a standard error of estimate.

As a first step in developing a regression equation the predictive values of several combinations of independent variables were investigated by calculating coefficients of multiple correlation between these variables and Physics 114. The results of these calculations are shown in Table XXI. Numbers appearing immediately above each test represent standard partial regression coefficients. These represent the proportional weight of each variable in determining the value of the predicted grade for that combination of variables. Letters that appear immediately under each test are those used in other tables to designate the particular test.

Those independent variables used in the first multiple correlation coefficient were; the Pre-Engineering Ability Test, American Council on Education Psychological Examination, and the college cumulative averages.

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[2]Haym Kruglak and Robert J. Keller, p. 144.

TABLE XXI

MULTIPLE CORRELATION COEFFICIENTS WITH PHYSICS 114

Predictive Variable			N	Correlation Coefficient
.298* Pre-Eng, Y_1	.082 ACE, Y_5	.409 Col. Cum. Av. Z_1	156	.574**
.139 Pre-Eng, Y_1	.228 Coop-Alg, Y_2	.377 Col. Cum. Av. Z_1	156	.597**
.258 Pre-Eng, Y_1	-.045 H.S. Av., X_1	.418 Col. Cum. Av. Z_1	156	.568**
.398 Coop-Alg, Y_2	-.307 H.S. Phys, X_3	.606 Col. Cum. Av. Z_1	50	.616**
.227 Pre-Eng, Y_1	.216 Col. Math. Av. X_3	.271 Col. Cum. Av. Z_1	147	.590**

*Standard partial regression coefficients

**Significant at the .05 level of confidence

These gave a correlation coefficient of .574 which was only .055 better than the zero-order correlation of .519 between the college cumulative average and Physics 114. Kruglak and Keller[3] found that multiple correlation was no better for predicting a grade in the first quarter of sophomore pre-engineering physics than the zero-order correlation with the freshmen year total grade average. Substitution of the Cooperative Algebra Test scores for the American Council on Education Psychological total scores only slightly improved the correlation, giving a value of .597.

Some other studies have shown that the inclusion of high school data has resulted in a larger coefficient of multiple correlation. In

[3]Ibid., p. 143.

most cases either rank in high school graduating class or the four-year high school grade point average was used. Since most high school transcripts of the sample did not indicate rank in graduating class, the high school grade point average was used. A combination of these, Pre-Engineering Ability scores, and college cumulative averages gave a multiple correlation coefficient of only .568. This was the lowest multiple correlation coefficient calculated. From Table XX of the intercorrelations between high school data and college data, one observes that the correlation between high school averages and college cumulative averages was only .470. When high school physics was substituted for high school averages, a coefficient of .616 resulted. This was the highest multiple correlation coefficient obtained. However, it was calculated from data on the 53, or approximately only a third of the total number of the sample, who had taken high school physics.

Although the several combinations of independent variables gave multiple correlation coefficients whose values were little better than the zero-order correlations for the cumulative average, Kruglak and Keller[4] have pointed out that there are many problems in which a combination of several variables is likely to give a higher predictive efficiency than a single variable. Hence, five multiple regression equations were developed using the combinations of variables in Table XXI.

The combination of the several variables included in the first multiple correlation coefficient were substituted in the general equation:

$$\hat{P} = \bar{P} + b_1(Y_1 - \bar{Y}_1) + b_2(Y_5 - \bar{Y}_5) + b_3(Z_1 - \bar{Z}_1)$$

Where $\hat{P}$ = predicted final grade in Physics 114, $\bar{P}$ = the mean final grade in Physics 114, b_1 b_2 b_3 are the partial regression coefficients,

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[4]Ibid., p. 144.

Y = Pre-Engineering Ability scores, Y_1 = American Council on Education Psychological Examination total scores, Z_1 = college cumulative averages, and $\overline{Y}_1$ $\overline{Y}_5$ $\overline{Z}_1$ are the means of the respective independent variables. The partial regression coefficients were arrived at by setting up three normal equations involving standard partial regression coefficients and zero-order correlation coefficients. These three equations were solved to give the three standard partial regression coefficients. Each of these standard partial regression coefficients, in turn, was multiplied by the ratio of the standard deviation of Physics 114 final grades to that of the variable concerned.

The final equation for the prediction of Physics 114 grades from the original scores for these independent variables was found to be:

$$\hat{P} = -.738 + .033\ Y_1 + .0042\ Y_5 + .775\ Z_1$$

In this equation, a student whose Pre-Engineering score was 40, whose American Council on Education Psychological Examination score was 95, and whose college cumulative average was 2.29, would have a predicted grade in Physics 114 of 1.967 (where A = 4, B = 3, C = 2, D = 1, F = 0). Predicted grades for each of the 156 students of the sample were calculated by the above formula. A coefficient of correlation between the predicted grades of the individual students and the actual grades received was then calculated. This gave a value of .585 which compared favorably with the coefficient of multiple correlation of .574 previously calculated.

One measure of the worth of the prediction equation would be to count the actual number of predicted grades that fall within the range of the grade earned by the respective students. However, a better measure of this is the standard error of estimate calculated by the following equation:

$$\sqrt{\frac{(1 - R^2)Sy^2}{n-3}}$$

Here "R" is the multiple correlation coefficient and Sy^2 is the sum of the squares of the deviations from the mean of the Physics 114 final grade. Using the data obtained for the first set of three independent variables, a standard error of estimate of 1.03 of a letter grade was calculated. This meant that two-thirds of the predicted grades should not have differed more than 1.03 of a letter grade from the actual grades earned. An actual count of the grades predicted from this equation showed that 62.90 per cent fell within one standard error of estimate. Over 95 per cent of the grades were within two standard errors of estimate and all were within three standard errors of estimate.

One may compare the relative predictive values of the independent variables by comparing the corresponding standard regression coefficients. In this combination of independent variables, the college cumulative average had the largest relative weight with a standard partial regression coefficient of .409. This is much larger than a standard partial regression coefficient of .298 for the Pre-Engineering Ability scores. The American Council on Education Psychological Examination had the smallest coefficient which was - .082.

A similar comparison was made for the second combination of independent variables. The Pre-Engineering Ability scores, the Cooperative Algebra results, and the college cumulative averages made up this combination. The substitution of the Cooperative Algebra Test scores for the American Council on Education Psychological Examination values slightly increased the multiple correlation coefficient. The prediction equation for this combination of independent variables was found to be:

$$\hat{P} = -0.953 + .015\ Y_1 + .025\ Y_2 + .715\ Z_1$$

Predicted final grades in Physics 114 were again calculated for each student of the sample. A correlation coefficient of .592 was found between the predicted and final grades for the 156 of the sample. For this combination of predictors, a value of 1.011 was arrived at as a standard error of estimate. This is very little better than the value of 1.03 found for the previous combination of variables. For this combination of variables, the standard partial regression coefficient was .377 for the college cumulative average, .228 for the Cooperative Algebra scores, and .139 for the Pre-Engineering Ability scores. Here again, the college cumulative average was the best predictor. That the Cooperative Algebra scores should outrank the Pre-Engineering Ability scores was not expected. A student by student comparison of the predicted and final grades in Physics 114 showed that, although the standard error of estimate was less, 66.60 per cent of the predicted grades fell within one standard error of estimate of the final grade.

The two previous combinations of predictive variables have included only information obtained on the students of the sample after they arrived at college. The value of developing a third prediction equation using Pre-Engineering Ability scores, high school averages, and college cumulative averages was investigated. Standard partial regression coefficients were calculated and found to be .418 for college cumulative averages, .258 for Pre-Engineering Ability scores, and -.045 for the high school averages. Using these values and the zero-order correlation coefficients, a multiple correlation of .568 was calculated. Since this was the lowest value obtained for a multiple correlation coefficient, there seemed little value in developing a regression equation.

Since high school physics grades had given the highest correlation coefficient with Physics 114 of any of the high school work, and the previous calculations had shown the Cooperative Algebra test scores and the college cumulative averages to be the best predictive variables of those investigated, a combination of these three was tried. Standard partial regression coefficients were .606 for the college cumulative averages, .398 for the Cooperative Algebra scores, and -.307 for high school physics grades. The multiple coefficient of correlation was found to be .616. Since this was the highest multiple coefficient calculated, a regression equation for these three independent variables was calculated. It was found to be:

$$\hat{P} = -1.658 + .0473\ Y_2 + .421\ X_3 + 1.337\ Z_1$$

This combination of variables gave a standard error of estimate of 1.046 of a grade point. Since approximately two-thirds of the sample had not had high school physics, this equation should not be considered as of equal value to the other two prediction equations.

A comparison of the errors in prediction of the combination of Pre-Engineering Ability scores, American Council on Education Psychological Examination scores, and college cumulative averages with those of the combination of Pre-Engineering Ability scores, Cooperative Algebra scores, and college cumulative averages gave some indication as to why it was not possible to predict the scholastic achievement of a high per cent of the students of a given group. For 58 students of the sample, the first combination of independent variables predicted a Physics 114 grade that differed from the final grade more than one standard error of estimate. Only 52 of the grades predicted by the second combination of variables fell outside one standard error of estimate for this equation. Yet 45 of the 58 predicted grades which fell outside the one standard error of estimate for the first combination of predictors also exceeded one standard error of estimate for the second combination of predictors.

Sixteen of the 45 students whose predicted grades fell outside of one standard error of estimate for both of the first two regression equations had also had high school physics. It is of interest to note that the fourth regression equation, a combination of the Cooperative Algebra scores, high school physics grades, and college cumulative averages, predicted a final grade in Physics 114 for 12 of these 16 students that was also outside one standard error of estimate for this combination of variables.

The 45 students for which both of the first two regression equations failed to predict Physics 114 grades within one standard error of estimate represented approximately 30 per cent of the sample. The regression equation involving high school physics failed to predict the Physics 114 final grade within one standard error of estimate for 12 or 75.00 per cent of the 16 of those 45 who had also had high school physics. These calculations seem to indicate that, for slightly better than 20 per cent of the students of this sample, none of the combinations of independent variables tried would predict their final grades in Physics 114 within one standard error of estimate. In all five combinations this standard error of estimate was approximately one letter grade.

A study of zero-order correlation coefficients would seem to indicate that the independent variables of greatest predictive value had been incorporated within the several multiple correlations. While the combination of Cooperative Algebra, high school physics, and college cumulative average gave the highest multiple correlation coefficient, the four other combinations gave coefficients which were only slightly less in value. This same combination of variables gave a standard error of estimate of 1.046 or approximately one letter grade. It might be concluded that there are several combinations of independent variables in the data of this sample that would predict the final grade in Physics 114 of approximately two-thirds of the sample within one letter grade.

CHAPTER IX

SUMMARY AND CONCLUSIONS

This has been primarily a study of articulation between a first course in college physics, Physics 114, and certain factors in the high school and college background of a group of 237 students who enrolled in Physics 114 in the fall of 1956 at Oklahoma State University.

In order to arrive at some homogenity among the students of the sample, certain selection criteria were applied to this group. Only those undergraduate students with a high school background in the continental United States, whose cumulative records were complete for all of the independent variables of the study, were included in the sample. This reduced the final sample to 156 students.

The achievement criterion or independent variable for this group was the final grade in Physics 114. Data on 19 different aspects of their academic careers made up the principal independent variables. Eight of these independent variables came from high school records, eight from standardized college entrance tests, and three from their records of achievement in college.

Zero-order correlation coefficients between all of the various independent variables and the achievement criterion, Physics 114, were calculated. Since the feasibility of developing a regression equation was one of the purposes of this study, multiple correlation coefficients for several combinations were calculated. For four of these combinations of independent variables, where multiple correlation resulted in higher coefficients, regression equations were developed.

High School Achievement. Since the dependent variable of this study was a science course, achievement in secondary science seemed a logical starting point. Only 53 or 33.97 per cent of the sample had taken a course in high school physics, 48.71 per cent in chemistry, and 108 or 69.23 per cent had had two or more years of science in high school. The total science mean grade was 2.682. Chemistry was slightly lower with a mean of 2.664, while the lowest of the three means achieved was 2.481 for the 53 in physics. Yet, for these 53, the mean of their total high school achievement was 2.839 as compared to 2.740 for the other 103 of the sample.

Over 90 per cent of the sample had taken two or more years of high school mathematics. Seventy-six of these had credit in Algebra II, and seven had done advanced work beyond this. The means for both total high school mathematics and Algebra II were at about the "B" minus level. While both the science mean and the mathematics mean were well above a "C" average, they were both below the mean achievement of 2.781 for the sample in all high school subjects. This high mean achievement for the sample would seem to indicate that those with stronger academic backgrounds tend to come to college.

College Achievement. The achievement of the sample was investigated in several aspects of their college work. Here again, a mean of 1.980 for Physics 114 was the lowest mean found. For the 53 students who had taken high school physics, the mean was 2.113 as compared to 1.912 for those who had not. This would seem to indicate that high school physics had helped these 53 students or that the slightly superior achievement they had shown in high school had been carried over to college.

To arrive at the mean of the mathematics background of the sample, the average mark of each student was used if that student had taken any college mathematics. For the 147 students who met the requirement, the mean achievement was 2.104. Since their mean for high school mathematics was 2.669, it was concluded that college mathematics was somewhat more difficult.

Mean achievement in college chemistry for 130 of the sample was 2.362. This was considerably better than the mean for both college physics and mathematics and was only slightly less than 2.272, the mean cumulative average. Since this cumulative average included all of the work taken in college, it would seem that students of the sample found physics and mathematics among their more difficult subjects. A value of 2.411 for the current average, when compared with the cumulative, indicated only a slight improvement during the semester in which they took Physics 114.

<u>Standardized Tests</u>. The results of four standardized tests were of interest to this study. Two of these, the American Council on Education Psychological Examination and the Cooperative Algebra Test, were administered at the time the students entered Oklahoma State University. The Pre-Engineering Ability Test and the Kuder Preference Record were taken soon after the sample started Physics 114.

Of all of the standardized tests, the Pre-Engineering Ability showed the highest correlation with Physics 114 with a coefficient of .446. The Cooperative Algebra Test was only slightly less effective with a correlation coefficient of .432 with Physics 114. All three correlation coefficients for the American Council on Education Psychological Examination scores were low. That the linguistic part should have the highest coefficient was rather unexpected.

Only three parts of the Kuder Preference Record showed correlation coefficients with Physics 114 of sufficient value to warrant additional study. These were the Computational scale with a coefficient of .182, the Scientific scale with a coefficient of .157, and the Literary scale whose coefficient was .242. All of these values were considered too low to include them in multiple correlation coefficients or multiple regression equations.

Multiple Correlation and Regression. The prediction value of several combinations of independent variables were investigated by calculating multiple correlation coefficients between these variables and Physics 114. These variables included the Pre-Engineering Ability scores, American Council on Education Psychological Examination scores, Cooperative Algebra scores, college cumulative averages, high school physics grades, and high school total averages. A combination of the Cooperative Algebra Test Scores, high school physics grades, and the college cumulative averages gave a value of .616, the largest multiple correlation coefficient for any of the combinations tried.

Four multiple regression equations were developed using the same four combinations of independent variables used in calculating multiple correlation coefficients. To give some idea of the value of these four equations, a standard error of estimate of prediction was calculated for each of the four combinations. This was found to be approximately one letter grade for all four equations. As a check on these values, predicted grades were calculated for each student of the sample for each of the four combinations of independent variables. Two-thirds or approximately 66 per cent of the predicted grades from each combination of variables should have fallen within one standard error of estimate. By actual count, the values ranged from 62.90 per cent to 66.90 per cent.

A comparison of the grades predicted by the first two combinations of independent variables showed that there were 45 students for which neither combination predicted a grade correct to within one standard error of estimate. Sixteen of the 53 predicted grades by the combination of variables including high school physics fell outside one standard error of estimate. Twelve of these grades were for students who were included in the 45 of the two previous combinations. From these calculations it was concluded that, for some 20 per cent of the sample, no combination of independent variables tried would predict their final grade within one standard error of estimate.

Conclusions. Findings of this study appeared to justify the following conclusions:

1. Correlation between most phases of the high school work of the sample and college physics was relatively low. A coefficient of .347 between Physics 114 and high school physics was the highest correlation found.
2. Those of the sample who had taken high school physics had a slightly higher mean grade in Physics 114 than those who had not taken high school physics.
3. Those students who had taken physics in high school had a slightly higher mean grade in all high school work than those who had not.

4. In general, standardized entrance test scores told more about probable success in college physics than did high school marks.
5. The best single predictor of final grades in Physics 114 was what the student had already done in college or the college cumulative average; r = .519.
6. Multiple correlation using college cumulative averages and additional independent variables did not improve the predictive efficiency of this "r" more than about 10 per cent; r = .616.
7. The standard error of estimate for prediction was found to be approximately one letter grade for each of four combinations of independent variables.
8. A comparison of the three grades predicted for each student of the sample by the three regression equations for which no combination of independent variables tried would predict a final grade within one standard error of estimate.

Recommendations. The fact that, for some 20 per cent of the sample, there was no combination of independent variables which would satisfactorily predict the final Physics 114 grade suggests the need for additional study. In a good many cases a very poor grade in Physics 114 seemed to be associated with a marked drop in total achievement during the semester. This was substantiated by a high correlation between the current achievement and Physics 114 grades; r = .835. It would seem evident that there were other factors influencing academic achievement which have not been included in this study. Some basis for excluding these cases from the prediction equation might have materially reduced the standard error of estimate for each of the four multiple regression equations.

Gough[1], investigating non-intellectual factors in predicting achievement, constructed a test where answers were judged to be indicative of personalogical areas pertinent to scholastic success. Correlation between this test and achievement was over .5. Such a test might be one way of predicting these abnormalities. The inclusion of such an approach in any future study of this nature is strongly recommended.

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[1]Harrison G. Gough, pp. 321-31.

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