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BY

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THE PREDICTION OF SUCCESS IN

EIGHTH GRADE ALGEBRA

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TABLE OF CONTENTS

LIST OF TABLES

THE PREDICTION OF SUCCESS IN

EIGHTH GRADE ALGEBRA

CHAPTER I

THE PROBLEM: ITS BACKGROUND AND DEFINITION

Introduction

Much has been written in previous years concerning the improvement of secondary school programs for academically bright students. Several approaches to this problem have been made, including acceleration of gifted students, enrichment of course offerings for these gifted students, and differentiated instruction with homogeneous grouping of students. The problem of offering challenging materials and instruction to bright students has been made more difficult by traditional curriculum patterns of blocks of material offered in specified years in secondary school programs. In the field of mathematics, for example, the normal pattern of course offerings for academically able students in junior high schools has traditionally been arithmetic in the seventh grade, arithmetic in the eighth grade, and algebra in the ninth grade.

The repetitious nature of seventh and eighth grade arithmetic has created a need for more challenging materials and instruction for the abler students in the eighth grade. This contention is supported by the recent release of two reports concerning instruction in mathematics. A panel of experts on the teaching of mathematics sponsored by the National Council of Teachers of Mathematics concluded that gifted students can profitably study algebra in either the seventh or eighth grades.[1] A report from the University of Maryland stated that many scientists and mathematicians contend that present mathematics curricula in junior high schools are generally inadequate and that lack of interest in mathematics and science by able students in high school and college may be caused largely by unhappy experiences in junior high school mathematics.[2] These, together with outside influences to offer more courses in mathematics and science at the secondary level, have prompted many schools to include algebra in the program of studies at the eighth grade level.

With the introduction of courses of this nature to a younger-than-ordinary student group, comes the attendant

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[1]The Daily Oklahoman (Oklahoma City), May 3, 1959, p. 3.

[2]"University of Maryland Study of Junior High School Mathematics," School Science and Mathematics, LVIII (February, 1958), p. 163.

problem of identification of students who have proper background, aptitude, and inclination to work with abstract materials. This study is concerned chiefly with isolating and evaluating factors which contribute to success in eighth grade algebra.

Need for the Study

There is no known research in the area of prediction of success in algebra in the eighth grade nor of isolation of factors contributing to that success. Several studies have been conducted, however, at the ninth grade level and will be discussed later in this chapter. The year's difference in age undoubtedly results in some differences in emotional, physical, and mental development. Prediction of achievement for the younger students is made more difficult by the lesser amount of common learning experience from which prediction may be made and from their less mature reaction to instruction. Wells reported that, even though a highly selected group of eighth graders were enrolled in an algebra course in the Lincoln, Nebraska, schools, it was necessary to divide the class on the basis of achievement in algebra into three groups for effective instruction.[1]

Since the probability is high that unselected students will not be able to understand the basic concepts of

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[1]D. W. Wells, "Modified Curriculum for Capable Students," The Mathematics Teacher, LI (March, 1958), p. 181.

algebra at the eighth grade level, the identification of capable students is of some importance. Shaw stated that, in addition to saving time for the student who might profit more from other courses, accurate prediction of success also helps eliminate frustration resulting from failure and helps prevent improper assignment of homework with studies that are too difficult for him to comprehend.[1]

Statement of the Problem

Purpose

The purpose of this study was to develop a procedure which could be used by professional educators in the identification of youngsters to whom algebra may be taught successfully at the eighth grade level. The problem, therefore, was to study and isolate factors which contribute to success in algebra in the eighth grade and to attempt to develop a multiple regression equation which would predict academic success in eighth grade algebra.

Delimitation of the Study

This study was limited to the seventy pupils enrolled in two classes in eighth grade algebra at Norman, Oklahoma, Junior High School during the first semester of the 1958-59 school year. No attempts were made to establish passing or

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[1]G. S. Shaw, "Prediction of Success in Elementary Algebra," Mathematics Teacher, XLIX (March, 1956), p. 173.

failing limits on the criterion variable or to determine accuracy of placement of pupils enrolled in these classes this school year.

Operational Definitions

In order to avoid ambiguity and to discourage repetitious explanation, the following terms were defined and were used in this context throughout the study:

(a) Subject is a student enrolled in eighth grade algebra in the Norman Junior High School during the first semester of the 1958-59 school year.

(b) Intelligence of each subject is his intelligence quotient as determined by performance on the *California Test of Mental Maturity*.

(c) Success in algebra is represented by the score on the *Seattle Algebra Test* given at the end of the first semester.

(d) Readiness in algebra is represented by the subject's score on the *Orleans Algebra Prognosis Test*.

(e) Interest is represented by scores on the *Kuder Preference Record* in the various interest areas.

(f) Arithmetic reasoning is grade placement on the sub-test of the *Stanford Achievement Test Battery*.

(g) Arithmetic computation is grade placement on the sub-test of the *Stanford Achievement Test Battery*.

(h) Study skills is grade placement on the sub-test of the Stanford Achievement Test.

(i) Reading skill is grade placement on the sub-test of the Stanford Achievement Test.

(j) Total achievement is grade placement on the total Stanford Achievement Test Battery.

Basic Assumptions

It was necessary to establish certain premises at the outset of a study of this type since there was a possibility of differences of opinion concerning values of factors which bear directly upon the outcome of the problem. In studies where small samples of subjects are used, where instruments are used to measure human behavior, or where devices are contrived to predict behavior, certain foundations of common understanding other than simple definition must be established. The following basic assumptions were, therefore, made for this study:

(a) That the population used in this study was a total population consisting of the seventy pupils enrolled in the eighth grade algebra classes in the Norman Junior High School in 1958-59. The bases for selection of the pupils were grades earned in the seventh grade and recommendations of seventh grade arithmetic teachers.

(b) That the regression equation was a valid predictor for all eighth grade pupils.

(c) That performance on the Seattle Algebra Test was a satisfactory measure of success in algebra.

(d) That the variables used in this study were variables pertinent to prediction.

(e) That the coefficient of contingency used to determine the reliability of the prediction was a reliable test of relationship between predicted scores and actual scores made on the Seattle Algebra Test.

(f) That scores and combinations of scores on the Kuder Preference reflected true interest patterns.

Background of Research

While several studies in prediction of success in algebra at the ninth grade level have been made, none was found to have been conducted for the eighth grade. Most of these studies were conducted to determine the effectiveness of a single predictor, the most popular being intelligence. Ross and Hooks reported a survey of prediction studies using intelligence as the single predictor and found that coefficients of correlation ranged between .12 and .69 with a median of .48.[1] A correlation of .48 indicates that prediction is only 12% better than chance.

Prognostic algebra tests were considered by many experts to be better predictors than intelligence tests

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[1]C. C. Ross and N. T. Hooks, "How Shall We Predict High School Achievement?" Journal of Educational Research, XXII (October, 1930), p. 191.

since they included background in mathematics in addition to intelligence in mathematics. Orleans, one of the pioneers in prognosis in mathematics, reported a correlation of .61 between The Orleans Algebra Prognosis Test and marks in algebra.[1] Seagoe also supported Algebra Prognosis tests over intelligence tests.[2] Segel reported a review of the literature on prediction which indicated that predictors of achievement in algebra ranged as follows: first, special algebra aptitudes; second, arithmetic tests; and third, intelligence tests.[3]

There was considerable interest among researchers, particularly during the 1930's, in developing prediction devices which would utilize a variety of factors. Ross and Hooks suggested that predictive ability may be improved by using several factors in a multiple regression equation.[4] Lee and Hughes stated, "There is a need, it seems, for determining the relative values of a number of these factors

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[1]J. B. Orleans, "A Study of Prognosis of Probable Success in Algebra and Geometry," The Mathematics Teacher, XXVII (May, 1934), p. 226.

[2]M. V. Seagoe, "Prediction of Achievement in Elementary Algebra," Journal of Educational Research, XXII (October, 1938), pp. 493-503.

[3]David Segel, "Measurement of Aptitude in Special Fields," Review of Educational Research, XI (February, 1941), pp. 42-56.

[4]Ross and Hooks, op. cit., p. 194.

when used together in discussing prediction."[1] They determined that intelligence quotient and algebra ability tests formed the best combination of predictive factors. Douglass stated that achievement in high school algebra may be predicted best by a combination of the following variables: a good prognostic test, intelligence, and average grades in the previous year or two years of school work.[2]

Most of the important studies in prediction of achievement in ninth grade algebra by multiple regression are presented in Table 1. It should be noted that multiple correlation coefficients tended to increase after 1941, probably because of increased efficiency of tests to measure and predict.

The most effective prediction equation was produced by Denkel in which a multiple correlation of .86 was attained using an algebra prognosis test, intelligence, arithmetic achievement, arithmetic grades, and an author-made test as predictors.

The most commonly used criterion of success was an algebra survey test. A test of this type provides opportunity for standardization, attainment of high reliability and

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[1]J. M. Lee and W. H. Hughes, "Predicting Success in Algebra and Geometry," School Review, XLII (March, 1934), p. 188.

[2]Harl R. Douglass, "The Prediction of Success in High School Mathematics," The Mathematics Teacher, XXVIII (December, 1935), p. 492.

TABLE 1

STUDIES INVOLVING PREDICTION OF ACHIEVEMENT IN NINTH GRADE ALGEBRA BY MEANS OF MULTIPLE REGRESSION

Author	Date	Elements of the Multiple Regression Equation	Coefficient of Correlation
May[1]	1923	1. Algebra achievement test[a] 2. Algebra prognostic test 3. Intelligence	$R_{1(23)} = .65$
Grover[2]	1932	1. Achievement test 2. Algebra prognosis test 3. Intelligence	$R_{1(23)} = .65$
Dictor[3]	1933	1. Algebra Survey Test 2. Test of Algebra Ability 3. Arithmetic Grades 4. Intelligence	$R_{1(234)} = .74$
Orleans[4]	1934	1. Grades in Algebra 2. Prognostic Test 3. Arithmetic Marks	$R_{1(24)} = .72$

[a]The element listed first for each study is the criterion variable. All subsequent elements are predictor variables.

[1]M. A. May, "Predicting Academic Success," Journal of Educational Psychology, XIV (October, 1923), p. 439.

[2]C. C. Grover, "Results of an Experiment in Predicting Success in Two Oakland Junior High Schools," Journal of Educational Psychology, XXIII (April, 1932), p. 313.

[3]M. R. Dictor, "Predicting Algebraic Ability," School Review, XLI (October, 1933), p. 605.

[4]J. B. Orleans, "A Study of Prognosis of Probable Success in Algebra and Geometry," The Mathematics Teacher, XXVII (May, 1934), p. 226.

TABLE 1--Continued

Author	Date	Elements of the Multiple Regression Equation	Coefficient of Correlation
Ayers[1]	1934	1. Algebra Grades 2. Algebra Prognosis Test 3. 8A Reasoning Test (teacher made) 4. Teacher Estimate 5. Intelligence	$R_{1(234)} = .70$
Dunn[2]	1937	1. Algebra Survey Test 2. Algebra Prognosis Test 3. General Achievement 4. Achievement in Arithmetic	$R_{1(234)} = .44$
Kellar[3]	1939	1. Algebra Survey Test 2. Algebra Computation 3. Ability to do Arithmetic Problems 4. Memory 5. Intelligence	$R_{1(2345)} = .81$
Clifton[4]	1940	1. Grades in Algebra 2. Reading 3. Arithmetic Reasoning 4. Dictation 5. Intelligence	$R_{1(2345)} = .57$

[1] G. H. Ayers, "Predicting Success in Algebra," School and Society, XXXIX (January, 1934), p. 18.

[2] W. H. Dunn, "The Influence of the Teacher Factor in Predicting Success in Ninth Grade Algebra," Journal of Educational Research, XXX (April, 1937), p. 581.

[3] W. R. Kellar, "The Relative Contribution of Certain Factors to Individual Differences in Algebraic Problem Solving Ability," Journal of Experimental Education, VIII (September, 1939), pp. 26-35.

[4] L. L. Clifton, "Prediction of High School Marks in Elementary Algebra," Journal of Experimental Education, VIII (June, 1940), p. 411.

TABLE 1--Continued

Author	Date	Elements of the Multiple Regression Equation	Coefficient of Correlation
Layton[1]	1941	1. Algebra Survey Test 2. Intelligence 3. 8th Grade Arithmetic Grades 4. Achievement Test in Arithmetic 5. Algebra Prognostic Test	$R_{1(2345)} = .76$
Guiler[2]	1944	1. Algebra Survey Test 2. Algebra Aptitude Test 3. Arithmetic Computation 4. Algebra Prognosis Test	$R_{1(234)} = .85$
Shaw[3]	1956	1. Algebra Survey Test 2. Intelligence 3. Algebra Aptitude Test 4. Reading Test	$R_{1(234)} = .77$
Denkel[4]	1959	1. Algebra Survey Test 2. Algebra Prognosis Test 3. Intelligence 4. Arithmetic Achievement 5. Arithmetic Grades 6. Author-made Test	$R_{1(23456)} = .86$

[1]R. B. Layton, "Study of Prognosis in High School Algebra," _Journal of Educational Research_, XXXIV (April, 1941), p. 604.

[2]W. S. Guiler, "Forecasting Achievement in Elementary Algebra," _Journal of Educational Research_, XXXVIII (Spetember, 1944), pp. 25-33.

[3]Shaw, _op. cit._, p. 177.

[4]R. E. Denkel, "Prognosis for Studying Algebra," _Arithmetic Teacher_, VI (December, 1959), p. 318.

validity, and for wide range of scores. Survey tests provide for much greater objectivity than grades; however, they limit depth of evaluation.

None of the above studies considered interest patterns as possible predictors, nor did they utilize a long series of possible predictor variables. This may be the result of the many exhaustive hours required for computation at the time the studies were conducted. Modern calculating devices, however, now permit use of a much more exhaustive series of predictor variables with a corresponding reduction of time and effort expended.

Experimental Procedure

A brief review of the procedure followed in this study is presented. Results of tests, development of the regression equation, and analysis of data will be presented in later chapters.

Selection of Predictor Variables

The review of research in prediction of success in ninth grade algebra revealed that successful predictor variables included intelligence, grade point averages, algebra prognosis tests, and achievement tests.

The use of interest patterns as predictors was conspicuous by its absence. There is indication, however, that interest might be used in this manner because of its close relationship to motivation and degree of application. May reported in a review of research that "the general conclusion . . . is that the most reliable means of predicting academic success is a combination of intelligence and a degree of application."[1] Wesman supported the use of interest as predictors as follows:

> The importance of interests and other personality traits for learning skills or acquiring knowledge needs no exposition. How well a person will acquire proficiency depends so much on his interest in his task, on his drive and goals, that the layman appreciates these conditioning factors as thoroughly as does the psychologist.[2]

It was decided that, since mechanical computers could be used to do most of the time-consuming work, an extensive list of predictor variables would be used. Various facets of intelligence, achievement, and interest would be used if their combinations did not cause inconsistencies in multiple regression. The following variables were chosen: (1) the criterion variable, (2) algebra prognosis test, (3) intelligence quotient, language factor, (4) intelligence quotient, non-language factor, (5) intelligence quotient, total mean factor, (6) mental age, (7) reading ability, (8) arithmetic reasoning, (9) arithmetic computation, (10) total arithmetic, (11) study skills, (12) total achievement, (13) grade point average, (14) grade in seventh grade

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[1]May, loc. cit., p. 39.

[2]A. G. Wesman, "What Is an Aptitude?" Test Service Bulletin, No. 36, The Psychological Corporation (August, 1948), p. 2.

arithmetic, (15) chronological age, (16) interest in computation, (17) interest in science, (18) interest in literature, (19) interest in computation, science, and literature, (20) interest in computation and science, (21) interest in science and literature, and (22) interest in computation and literature.

Administration of Predictor Tests

The following tests were administered to the subjects during May, 1958: The Stanford Achievement Test Battery, California Test of Mental Maturity, Kuder Preference Record, and the Orleans Algebra Prognosis Test. The test results were not used for selection of subjects for the study but were used in order to develop the prediction formula in the proposed study.

The Instructional Period

The subjects were enrolled in two sections of beginning algebra taught by two regular mathematics teachers of the Norman Junior High School faculty each of whom possessed life certificates in mathematics. These teachers used the same ninth grade algebra textbook and other instructional materials. These algebra sections were taught during the Fall semester of the 1958-59 school year, and the length of the instructional period was the same for each section.

The total number of subjects was 70 at the beginning of the study with 35 in each class. "N" for the study, however, was 57 since this was the number of subjects remaining at the end of the semester.

At the end of the first semester, the Seattle Algebra Test was administered to all subjects. Scores on this test were considered as the criterion of success.

Computation of Coefficients of Correlation

The values of the predictor and criterion variables were entered on IBM cards. The mean and standard deviation for each variable and the coefficient of correlation for each pair of variables were computed at the computer laboratory of the University of Oklahoma. The coefficients of correlation were placed in a matrix and the Wherry-Doolittle method of development of a multiple regression was utilized. A brief explanation of the Wherry-Doolittle method follows.

The Wherry-Doolittle Method of Test Selection

The amount of calculation necessary for utilization of the original Gaussian multiple regression becomes prohibitive where several variables are to be used as predictors. Modifications by Wherry and Doolittle, however, have made use of the equation practical for hand operations as described by Garrett:

> The Wherry-Doolittle test selection method . . . provides a method of solving certain types of multiple correlation problems with a minimum of labor. This

> method selects the tests of the battery analytically and adds them one at a time until a maximum R is obtained . . . By use of the Wherry-Doolittle Method we can (1) select those tests (e.g., three or four) which yield a maximum R with the criterion and discard the rest; (2) calculate the multiple R after the addition of each test stopping the process when R no longer increases; (3) compute a multiple regression equation from which the criterion can be predicted with the highest precision of which the given list of tests is capable.[1]

The general equation in standard score form developed by the above method was[2]

$$\tilde{Z}_1 = \beta_{12.34\ldots n}\, Z_2 + \beta_{13.24\ldots n}\, Z_3 + \ldots + \beta_{1n.23\ldots(n-1)} Z_n \quad (1)$$

Where $\tilde{Z}_1$ was the best estimate of the standard score on the criterion test, β's were weights for each variable as determined by the formula, and Z's represented standard scores made by each student on the selected tests. The equation was then converted into raw score form by use of the formula $b_1 = \frac{\sigma_1}{\sigma_i}\beta_i$ and by conversion of standard scores into raw scores. The resulting general equation was

$$\tilde{X}_1 = b_{12.34\ldots n}X_2 + b_{13.24\ldots n}X_3 + b_{1n.23\ldots(n-1)}X_n - K \quad (2)$$

where

$\tilde{X}_1$ = the best estimate of each pupil's performance on the Seattle Algebra Test

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[1]H. E. Garrett, Statistics in Psychology and Education (New York: Longmans, Green and Company, 1944).

[2]Ibid., 393.

k = constant

X = the pupil's raw score on that particular predictor variable

b = partial regression coefficients which were weights to be given each variable, X, chosen as a predictor variable. The weights were represented by the formula $b_{12.34\ldots n} = r_{12.34\ldots n} \frac{\sigma_{1.234\ldots n}}{\sigma_{2.134\ldots n}}$, where $r_{12.34\ldots n}$ was the coefficient of partial correlation between the criterion variable, X, and a predictor variable X_2, with common effect of other removed. σ's were standard deviations of the variable indicated with the variation of other variables removed.

The reliability, R, of the regression equation may be computed by use of the following formula:[1]

$$R_{1(23\ldots n)} = \sqrt{1 - \frac{\sigma^2_{1.23\ldots n}}{\sigma^2_1}} \qquad (3)$$

where

$R_{1(23\ldots n)}$ = the coefficient of multiple correlation

σ_1 = the standard deviation of the criterion scores

$\sigma_{1.23\ldots n}$ = the variability left in the criterion variable after the variability of the predictor tests have been held constant through partial correlation.

Standard error of the estimate of the criterion variable, $\tilde{X}_1$, may be computed by the formula,

$$\sigma_{\tilde{X}_1} = \sigma_1 \sqrt{1 - R_{1(23\ldots n)}} \qquad (4)$$

The reliability of the equation may be tested further by computing the coefficient of contingency of predicted

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[1]Ibid., 395.

scores for each pupil and his actual score made. Garrett stated that the contingency coefficient, C, approaches the value of the correlation coefficient when grouping is relatively fine, that is, when the table has at least 5 x 5 categories. The formula for computing the contingency is:[1]

$$C = \sqrt{\frac{\chi^2}{N + \chi^2}} \qquad (5)$$

The following basic assumptions must be met for all data used in the regression equation: (1) the distribution of scores for each variable must be normal, (2) there must be linear relationship between correlated variables, and (3) there must be homoscedasticity in the relationship of variables.

Overview of the Following Chapters

In Chapter II the data are analyzed and the multiple regression equation is formed and tested for accuracy. Chapter III contains the summary of the study, conclusions, recommendations, and implications for further study.

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[1] *Ibid.*, 368.

CHAPTER II

PRESENTATION AND ANALYSIS OF DATA

Data of the study are presented and analyzed in this chapter in the following order: (a) results of the criterion and predictor tests; (b) development of the multiple regression equation; (c) tests of basic assumptions; (d) the test of accuracy of prediction and of the elements of the formula; and (e) using the formula.

Results of the Criterion and Predictor Tests

At the end of the first semester the Seattle Algebra Test, which was to serve as criterion of success, was administered to the two eighth grade algebra classes. The mean scores and standard deviations of this test along with those of the predictor variables are listed in Table 2.

Although it has been stated that the purposes of this study do not include determination of the success or failure of students enrolled in algebra at the eighth grade level, it should be noted that the mean score of 32.49 on the criterion test was well above the mean of 24.5 scored by the ninth grade norming group. In fact, over eighty-nine

TABLE 2

VARIABLES WITH MEANS AND STANDARD DEVIATIONS

(N = 57)

Variable	Mean	Standard Deviation
1. Criterion Variable (raw score)	32.49	5.75
2. Orleans Algebra Aptitude Test (raw score)	65.39	11.57
3. Intelligence Quotient, Language Factor	123.79	9.47
4. Intelligence Quotient, Non-Language Factor	113.91	12.07
5. Intelligence Quotient, Total Mean Factor	119.04	8.54
6. Mental Age Total Mean Factor (in months)	185.58	15.04
7. Average Reading (grade placement)	10.95	1.19
8. Arithmetic Reasoning (grade placement)	11.02	.85
9. Arithmetic Computation (grade placement)	10.46	.84
10. Arithmetic Average (grade placement)	10.76	.77
11. Study Skills (grade placement)	11.25	1.01
12. Battery Media (grade placement)	10.82	.83
13. Mean Grade Point Average (four point scále)	3.54	.50
14. Grade Point Average 7th Grade (four point scale)	3.75	.31
15. Chronological Age (in months)	156.82	5.45
16. Interest in Computation (raw score)	27.00	9.10
17. Interest in Science (raw score)	39.63	15.86
18. Interest in Literary (raw score)	19.72	6.9
19. Total Interest (raw score)	86.18	19.76
20. Interest in Computation and Science (raw score)	66.63	21.23
21. Interest in Science and Literature (raw score)	59.35	14.42
22. Interest in Computation and Literature (raw score)	46.70	10.06

per cent of the subjects scored above the median of the norm, with fifty per cent scoring above the seventy-fifth percentile. Wells reported similar findings in an experiment involving comparable groups of eighth and ninth grade students taking algebra. He stated that of the combined distribution of scores on the final examination, fifteen of the top twenty-five scores were earned by eighth grade students. He hypothesized that they were motivated to achieve more nearly up to their ability because they were members of a select group.[1]

It should be noted that the mean intelligence quotient for the group is 119.04, well above the mean of 100 and within one point of what is generally accepted as the "bright" range. The I. Q. scores ranged from 104 to 149 with a standard deviation of 8.54. This low deviation, compared to the standard deviation of 16 for the entire population, adversely affected the power of the I. Q. scores as predictors since prediction is related directly to variation.

Achievement level based on scores on the Stanford Achievement Test and grade point average was quite high. Grade placement scores on the achievement tests were generally three years above the students' actual grade of 7.9. Grade point averages for the seventh grade were 3.75 and

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[1]Wells, loc. cit., p. 182.

3.54 in total grades and mathematics, respectively, based on a four point scale. Standard deviations for both achievement test scores and grade point averages were low, thus lowering the power of these variables to predict in this study.

Development of the Regression Equation

The intercorrelations of the twenty-two variables, including the criterion variable, are represented by the matrix of correlation coefficients shown in Table 3. The Wherry-Doolittle method of test selection was utilized to develop a multiple regression equation. Use of this method permitted selection of the predictor variable which contributed to the greatest amount of variation in the criterion variable, and selection of successive variables which contributed most when effects of preceding variables had been eliminated. Predictor variables were selected one at a time, and the multiple correlation was computed after selection of each variable. The Wherry shrinkage formula was applied to remove chance error from the correlation coefficient. The resulting correlation is represented by $\bar{R}$.

The value which each selected predictor will have in the formula was also determined by the Wherry-Doolittle method and was presented as a Beta weight in the general regression equation in standard score form. The selected tests are listed in Table 4 in the order of isolation. The

TABLE 3

[illegible]

	1	2	3	...	22
1	1.00	[illegible]	.577	[illegible]	[illegible]
2		1.00	[illegible]	[illegible]	[illegible]
3–20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21				1.00	.387
22					1.00

1. [illegible]
2. [illegible]
3. [illegible], I[illegible] P[illegible]
4. I[illegible], [illegible]-[illegible]
5. I[illegible], [illegible]
6. [illegible]
7. [illegible]
8. A[illegible]
9. A[illegible] C[illegible]
10. [illegible]
11. [illegible]
12. [illegible]
    [illegible]
13. [illegible] P[illegible], [illegible]
14. [illegible]
15. [illegible]
16. Interest in [illegible]
17. Interest in [illegible]
18. Interest in Literature
19. Total Interest in [illegible], [illegible], and Literature
20. Total of Interest [illegible]
21. Total of Interest [illegible] Literature
22. Total of Interest [illegible] Literature

TABLE 4

PREDICTOR TESTS IN ORDER OF SELECTION WITH BETA NUMBERS AND WEIGHTS AND WITH CUMULATIVE SHRUNKEN COEFFICIENTS OF CORRELATION

Predictor Tests Selected	Beta Number	Beta Weights	Cumulative $\overline{R}$
Intelligence Quotient Total Mean Factor	β_5	.465	.6030
Interest in Literature and Science	β_{21}	-.415	.6725
Orleans Algebra Prognosis Test	β_2	.276	.7328
Arithmetic Computation	β_9	.269	.7600

Beta number, beta weight, and cumulative $\overline{R}$ are listed for each test. It may be noted that intelligence quotient, which correlated highest with the criterion variable, was the first test to be selected. The second selected test, interest in literature and science, correlated negatively with the criterion variable and served as a suppressor eliminating some of the extraneous factors of the first selected test.

The third and fourth predictors, Orleans Algebra Prognosis Test and arithmetic computation, respectively, were selected resulting in a multiple correlation, $\overline{R}$ = 0.7600. The selection of a fifth test raised the multiple correlation only .0121, and it was decided to use only four predictors in the formula since economical application of the formula by classroom teachers would be impaired by an excessive number of terms.

The multiple regression equation was formulated by the statement in algebraic form that the best estimate of the standard score on the Seattle Algebra Test for each student is equal to the sum of the products of the Beta weights and standard scores he made on each selected test. The resulting equation was

$$\tilde{Z}_1 = .465Z_5 - .415Z_{21} + .276Z_2 + .269Z_9 \qquad (6)$$

where

$\tilde{Z}_1$ = the best estimate of a student's score on the Seattle Algebra Test in standard score form,

Z_5 = the student's intelligence quotient in standard score form,

Z_{21} = the student's interest in science and literature in standard score form,

Z_2 = the student's score on the Orleans Algebra Prognosis Test in standard form, and

Z_9 = the student's placement in arithmetic computation in standard score form.

In order that the formula could be used more easily and economically, it was converted to a formula based on original scores as follows:

$$\tilde{X}_1 = .313X_5 - .165X_{21} + .137X_2 + 1.841X_9 - 23.18 \qquad (7)$$

where $\tilde{X}_1$ is the predicted raw score on the Seattle Algebra Test; X_5, X_{21}, X_2, and X_9 represent original scores on selected tests; and 23.18 is a constant. This is the form recommended for use by classroom teachers.

The shrunken multiple correlation coefficient, $\bar{R}_{1[259(21)]}$, was 0.7600 with a standard error of the estimate of the criterion score of 3.74. That is, the actual scores made by students will not vary from their predicted scores over 3.74 points more often than 32 per cent of the time. The multiple correlation was significant at the .01 level of significance using N - k - 1, or 52, degrees of freedom where N was the number of subjects and k was the number of predictors.[1]

Results of Tests of Normality of Distribution, Linearity of Regression, and Homoscedasticity

Tests for normality of distribution, linearity of regression, and homoscedasticity for all four selected predictor variables and the criterion variable were conducted in the following manner:

(1) The normality of the distribution of scores in each variable was determined by use of the chi-square test of significance with actual scores placed in six categories and tested for difference from normal distribution. None of the variables deviated significantly from normality with $\chi^2_{.05}$ serving as criterion.[2] The results are shown in Table 5.

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[1]H. M. Walker and Joseph Lev, Statistical Inference (New York: Henry Holt and Company, 1953), p. 324.

[2]A. L. Edwards, Experimental Design in Psychological Research (New York: Rinehart and Company, Inc., 1956), p. 406.

TABLE 5

RESULTS OF TESTS OF NORMALITY OF THE DISTRIBUTIONS OF SCORES ON THE CRITERION AND PREDICTOR VARIABLES

Variables	Obtained χ^2	$\chi^2_{.05}$	Significance
Seattle Algebra Test (Criterion variable)	1.924	11.070	Not significant
Intelligence Quotient	10.728	11.070	Not significant
Interest in Science and Literature	1.728	11.070	Not significant
Orleans Algebra Prognosis Test	1.174	11.070	Not significant
Arithmetic Computation	1.628	11.070	Not significant

(2) Linearity of regression for each pair of variables was determined by computing the ratio of variance from the regression line of a scatter diagram plot and the variance from column means. None of these ratios was significant at the .05 level of significance.[1] The results are shown in Table 6.

(3) Tests for homoscedasticity between each pair of variables consisted of application of Bartlett's test of homogeneity of variance of scores in columns of scatter diagrams for each pair of variables. None was significant at the .05 level of significance.[2] Table 7 shows the results.

[1]Walker and Lev, op. cit., p. 246.

[2]Ibid., 194.

TABLE 6

RESULTS OF TESTS OF LINEARITY OF REGRESSION BETWEEN VARIABLES (N = 57)

Variables	Obtained F ratio	$F_{.05}$	Significance
Criterion and Intelligence Quotient	1.025	5.85	Not significant
Criterion and *Orleans Algebra Prognosis Test*	.391	2.80	Not significant
Criterion and Arithmetic Computation	.818	3.03	Not significant
Criterion and Interest in Literature and Science	1.009	2.80	Not significant
Intelligence Quotient and *Orleans Algebra Prognosis Test*	1.702	3.32	Not significant
Intelligence Quotient and Arithmetic Computation	.670	2.80	Not significant
Intelligence Quotient and Interest in Science and Literature	.494	2.80	Not significant
Orleans Algebra Prognosis Test and Arithmetic Computation	1.192	3.03	Not significant
Orleans Algebra Prognosis Test and Interest in Science and Literature	.725	2.80	Not significant
Arithmetic Computation and interest in Science and Literature	.617	2.80	Not significant

TABLE 7

RESULTS OF TESTS OF HOMOSCEDASTICITY BETWEEN VARIABLES

Variables	Obtained χ^2	$\chi^2_{.05}$	Significance
Criterion and Intelligence Quotient	2.645	7.815	Not significant
Criterion and Orleans Algebra Prognosis Test	5.240	9.488	Not significant
Criterion and Arithmetic Computation	2.966	9.488	Not significant
Criterion and Interest in Literature and Science	7.327	9.488	Not significant
Intelligence Quotient and Orleans Algebra Prognosis Test	1.946	7.815	Not significant
Intelligence Quotient and Arithmetic Computation	6.491	9.488	Not significant
Intelligence Quotient and Interest in Science and Literature	3.100	7.815	Not significant
Orleans Algebra Prognosis Test and Arithmetic Computation	4.231	9.488	Not significant
Orleans Algebra Prognosis Test and Interest in Science and Literature	7.234	9.488	Not significant
Arithmetic Computation and Interest in Science and Literature	4.034	9.488	Not significant

Tests of the Accuracy of Prediction and of the Elements of the Formula

Coefficient of Contingency

The accuracy of the coefficient of multiple correlation, $\bar{R}$, was authenticated by the use of the statistic coefficient of contingency. Garrett stated that, under certain conditions, the relationship between the coefficient of correlation and the coefficient of contingency is very close. Those conditions were that (1) the grouping be fairly fine--5 x 5 fold or finer; (2) the sample be large; (3) the two variables may be classified in categories; and (4) the variables are normally distributed.[1] The above conditions were met by the variables utilized in this problem.

In order to obtain the coefficient of contingency, scores were predicted for each individual by use of the multiple regression equation and the values of predictor variables for each individual. The predicted scores were placed in a scatter diagram in relationship with scores actually made on the Seattle Algebra Test. The resulting scatter diagram is shown by Table 8. The coefficient of contingency, C, was .7487 which compared favorably with the shrunken $\bar{R}$ of .7600.

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[1]Garrett, op. cit., p. 368.

TABLE 8

CONTINGENCY TABLE OF SCORES PREDICTED FOR EACH STUDENT AND HIS ACTUAL SCORE
(N = 57)

Predicted Scores \ Actual Scores	20 - 22	23 - 25	26 - 28	29 - 31	32 - 34	35 - 37	38 - 40	41 - 43	44 - 46
44 - 46									
41 - 43								1	
38 - 40				1		1	3	1	2
35 - 37				2	2	3	2	1	
32 - 34		1		4	3	2	2		
29 - 31		2	2	5	3	1	1		
26 - 28	2	1	5	3					
23 - 25									
20 - 22	1								

$\chi^2 = 72.71$

$$C = \sqrt{\frac{\chi^2}{N + \chi^2}} = \sqrt{\frac{72.71}{57 + 72.71}} = \sqrt{.5606} = .7487$$

Variations of Predicted Scores from Actual Scores

The average variation of predicted scores on the Seattle Algebra Test from actual scores made was 2.92. The greater individual variations occurred at the upper and lower extremes of the distribution of scores. This greater variation at the extremes is normal since predicted scores tend to regress toward the mean.

Test of Accuracy for Beta Weights

The accuracy of Beta weights in the prediction equation in standard score form was determined by the equation[1]

$$R^2_{1[5(21)29]} = B_5 r_{15} + B_{21} r_{1(21)} + B_2 r_{12} + B_9 r_{19} \qquad (8)$$

in which Beta weights were those listed in Table 4, and r in each term was the zero order coefficient of correlation between the criterion variable and the selected predictor test. Substituting numerical values for B's and r's in the equation resulted in

$$R^2_{1[5(21)29]} = .465(.603) - .415(-.101) + .276(.493) + .269(.530)$$

$$= .280 + .042 + .136 + .143$$

$$= .6010 \qquad (9)$$

Then

$$R_{1[5(21)29]} = .7753$$

[1]Garrett, *op. cit.*, p. 396.

Application of the shrinkage formula, $\overline{R}^2 = \frac{(N-1)R^2 - (M-1)}{N-M}$, which removed chance error, resulted in $\overline{R}^2 = .6004$. $\overline{R}$ equalled .7605 which compared favorably with shrunken coefficient of correlation of .7600 and established accuracy for Beta weights.[1]

Contribution of Elements to Total Variation

The squared multiple correlation coefficient of .6010 in formula 9 indicated that 60 per cent of the variation of the scores on the Seattle Algebra Test was attributed to differences in students measured by the four prediction variables. The product of the Beta weight and the coefficient of correlation in each term revealed the amount of variation caused by each predictor variable. The amount contributed by each predictor test is as follows: intelligence quotient, 28 per cent; interest in literature and science, 4 per cent; Orleans Algebra Prognosis Test, 14 per cent; and arithmetic computation, 14 per cent.

Using the Formula

In order for the formula to be used, it will be necessary to obtain scores on the four predictor variables during the month of May for each seventh grader who is to be considered for eighth grade algebra. The resulting

[1]R. J. Wherry, "A New Formula for Predicting the Shrinkage of the Coefficient of Multiple Correlation," Annals of Mathematical Statistics, II (1931), p. 440.

scores are to be entered in the formula. The result is the best estimate of his score on the Seattle Algebra Test.

The application of the formula to hypothetical sets of data is presented. The scores made by two students, A and B, on each variable are listed below in Table 9.

TABLE 9

HYPOTHETICAL DATA FOR TWO STUDENTS

Predictor Variable	Variable Number	Student A	Student B
I. Q., California Test of Mental Maturity	X_5	128	100
Interest in Science and Literature Combined, Kuder Preference Record	X_{21}	60	78
Orleans Algebra Aptitude Test	X_2	83	40
Arithmetic Computation, Grade Placement, Stanford Achievement Test	X_9	11.1	8.3

Substitution of the scores of student A in the formula

$$\tilde{X}_1 = .313X_5 - .165X_{21} + .137X_2 + 1.841X_9 - 23.18$$

resulted in

$$\tilde{X}_1 = (.313)(128) - (.165)(60) + (.137)(83) + (1.841)(11.1) - 23.18.$$

The resulting score was 38.3. The best estimate of

Student A's score on the Seattle Algebra Test, therefore, was 38.3 plus or minus 3.74, which was the standard error of the estimate. This score was well above the mean for the norming group.

Substitution of B's scores resulted in 16.01 $\pm$ 3.74 as the best estimate of his score, which was well below the mean of the norming group.

It is suggested that students whose predicted scores fall below the score which represents the 17th percentile on the Seattle Algebra Test norm be discouraged from taking algebra in the eighth grade. This recommendation is based on the proposed grading of Rinsland which utilizes five equal divisions for grades A, B, C, D, and F in a normal distribution.[1]

Summary

At the end of the first semester the 57 students enrolled in the two eighth grade algebra classes were administered the Seattle Algebra Test, which was to serve as criterion of success in the study. The results of this test and the twenty-one predictor variables selected for the study were utilized to develop a multiple regression equation which would predict scores of similar pupils on the Seattle Algebra Test. The Wherry-Doolittle method of

[1]Henry D. Rinsland, "Clinical Method of Grading" (University of Oklahoma, 1952), p. 10. (Mimeographed.)

predictor selection, which permits identification of the best predictors, was utilized in the development of the formula.

Four predictor variables were isolated for use in the formula. They were intelligence quotient, determined by use of the California Test of Mental Maturity; combined raw scores of interest in science and literature on the Kuder Preference Record; raw scores on the Orleans Algebra Aptitude Test; and grade placement on the arithmetic computation sub-test of the Stanford Achievement Test.

The resulting formula was

$$\tilde{X}_1 = .313X_5 - .165X_{21} + .137X_2 + 1.841X_9 - 23.18$$

in which X_1 is the best estimate of a student's score on the Seattle Algebra Test, and X's represent his score on the predictor variables in the order given in the preceding paragraph. 23.18 is a constant.

The seventeen other possible predictors did not contribute significantly to the power of the formula to predict and were discarded.

CHAPTER III

SUMMARY AND CONCLUSIONS

Summary

The inclusion of algebra for academically able eighth grade students in the curriculum of some schools has created a problem of identification of students who have proper background, aptitude, and inclination to work with abstract materials at this level. The purpose of this study was to isolate and examine factors which contribute to success in algebra in the eighth grade and to attempt to develop a multiple regression equation which would predict success in eighth grade algebra.

The subjects for the study were the 57 students enrolled in two classes of eighth grade algebra at Norman Junior High School, Norman, Oklahoma, during the fall semester of the school year 1958-59. They were selected for the course by officials of the school on the bases of their past academic records and recommendations of their seventh grade mathematics teachers. At the end of their seventh year, 70 students were selected for enrollment in eighth grade algebra and, consequently, as subjects for the study. At that time they were administered a battery of tests which, with other selected factors, were to serve as predictors of success in eighth grade algebra. The tests administered were the California Test of Mental Maturity, the Orleans Algebra Prognosis Test, the Stanford Achievement Test, and the Kuder Preference Record.

The two algebra courses were taught by two regular members of the mathematics department of the Norman Junior High School. The teachers used the same ninth grade algebra textbooks and other materials, and the length of the instructional period was the same for both classes.

At the end of the fall semester, the Seattle Algebra Test was administered to the 57 students who were still enrolled in the two classes. The results of this test served as the criterion of success in algebra.

A total of twenty-one predictor variables were selected from scores of the tests given at the end of the seventh year, school grades, and chronological age. The mean and standard deviation for each variable and the coefficients of correlation for each pair of variables were computed. The variables included the criterion variable. The intercorrelations were placed in a matrix, and the Wherry-Doolittle method of development of a multiple regression equation was utilized. By use of this method, the best predictors were selected, the coefficient of multiple correlation was computed, and the multiple regression formula was developed. Four predictor variables were isolated for use in the formula, and the others were discarded. The resulting prediction formula was

$$\tilde{X}_1 = .313X_5 = .165X_{21} + .137X_2 + 1.841X_9 - 23.18$$

where

$\tilde{X}_1$ = the best estimate of a student's raw score on the Seattle Algebra Test

X_5 = the student's intelligence quotient determined by the California Test of Mental Maturity

X_{21} = the student's combined raw scores of interest in science and literature on the Kuder Preference Record

X_2 = the student's raw score on the Orleans Algebra Aptitude Test

X_9 = the student's grade placement on the arithmetic computation sub-test of the Stanford Achievement Test

23.18 = Constant.

The coefficient of multiple correlation was 0.76, and the standard error of the estimate of the predicted score was 3.74. Further evidence of the accuracy of the formula was shown by the close approximation of the coefficient of multiple correlation to the coefficient of contingency of scores predicted by the formula and actual scores made by the students.

Conclusions

The multiple correlation of 0.7600 indicated that the predictor variables selected had a fairly high relationship to ability to achieve in algebra in the eighth grade. As was expected, the formula developed included a wide variety of predictors.

The selection of general intelligence as the first and most efficient predictor supported Dexter's contention that "general endowment rather than specific endowment is the essential factor for successful work in mathematics."[1]

The influence of interests was indicated by the negative contribution of interest in science and literature to the prediction formula. It was hypothesized that the negative relationship was brought about by the fact that a high combination score represented a high level of interest in activities other than computation, which was the third area of interest considered.

The selection of the prognostic test as the third predictor indicated that ability to respond to instruction in working with abstractions is a significant factor in working algebra problems. The Orleans Algebra Prognosis Test consists of "lessons" and tests based on those "lessons."[2]

Arithmetic computation was selected as the fourth predictor. It should surprise no one since this ability is

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[1]E. S. Dexter, "Does Mathematics Require Specialized Endowments?" School and Society, XLIV (August, 1936), p. 224.

[2]O. K. Buros (ed.), The Fourth Mental Measurements Yearbook (Highland Park: The Gryphon Press, 1953), p. 396.

fundamental in solving problems where quantitative factors are involved.

Recommendations

It is recommended that the multiple regression equation developed in this study be used in the selection of students to be enrolled in eighth grade algebra. It should be realized, however, that the formula should not be used alone but in conjunction with other factors including teacher estimate of the student's ability, motivation, and emotional maturity.

It seems imperative that appropriately designed courses of study in algebra for brighter students be included at an earlier stage in junior high school curriculum and that the senior high school offerings be altered to provide for more rapid advancement of these students in mathematics.

Implications for Further Study

The progress made by accelerated students should be checked to determine the effects of rapid advancement on their performance not only in junior high school but also in senior high school and in college. They should be compared with similar groups of students proceeding through more traditional curricula.

Further investigation into predetermining the degree of application which students will exert in various subjects should be conducted. Possible contributing factors which might be considered are interests, educational objectives, desire to understand, competitive spirit, work load, and emotional factors.

It is suggested that a study be conducted to determine the comparative merits of intelligence quotient and mental age in ability to work with abstractions and with creative activities including written composition and art. The traditional curriculum appears to be based on the supposition that mental and physical maturity are the prime factors in ability to do the more difficult studies. Additional study of factors contributing to success in other academic areas should be conducted at the junior high school level.

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