AN EVALUATION OF THE FUNCTIONAL THINKING ABILITIES OF FIFTY NINTH GRADE PUPILS IN MATHEMATICS

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PREFACE

Education in its effort to socialize all subjects into a core curriculum had many problems of adjusting some of the key courses. Mathematics is not the least of these. We have, for instance, witnessed algebra taken out of a freshman curriculum and general mathematics put in its place where students have had no choice of what they wish to take. In effect all freshman are put into general mathematics.

The aptitudes of many pupils are not equal to a course where a smattering of many fields of mathematics is thrust on them without analysis of what these pupils can do or what they will most need. The ability of other pupils should give them an opportunity to choose the course of study they plan to follow. By finding what relation certain specific abilities have to functional mathematics it might be possible to analyze and predict what would guarantee or encourage success in mathematics, or what procedures for adjustment could be made. In other words, what provision can be planned for lack of or ability for mathematics.

By choosing some aptitudes that might have direct bearing on what constitutes such ability and testing individual pupils, the writer has attempted to show the relative correlation of these various aptitudes with functional thinking.

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CHAPTER ONE

INTRODUCTION

THE GENERAL PROBLEM--The resulting confusion that many pupils experienced when put into a general mathematics class, where no segregration took place except by accident, has brought to attention the fact that some future plan must contain more specific analysis of the pupils' aptitude.

> Educational programs are always set up originally for the teaching of human beings. They are designed to give individual learners those patterns of conduct and personality which the community considers desirable. They are directed towards total behavior changing goals. 1

> It appears therefore that the high school is not adapting itself to the inequalities in native mental endowment of its students as well as it should, nor as well as the elementary school;...On the face of our results it appears that many students in high schools are working far below their best standard of attainment and so are acquiring habits of laziness and ineffeciency because their work is ill adapted to their mental strength and needs. 2

There is too, the pupil for whom mathematics has a true repulsion and investigation of the background of such a feeling seems desirable.

> There are some people, it is true, who seem to have an incurable antipathy toward mathematics in any form, and in such cases little is to be gained by making the subject compulsory beyond the point of obvious utilitarian values unless this antipathy can be overcome. The potential values of the subject are so considerable, however, that every encouragment should be given to students to carry on their work in this field even though it may not be required. 3

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1. Charles H. Butler and F. Lynwood Wren, The Teaching of Secondary Mathematics,(New York: McGraw-Hill B ook Company, 1941),p.29.
2.W. F. Book, The Intelligenee of High School Seniors, (New York; The Macmillan Co., 1922), p. 54.
3. Op. Cit., Butler and Wren, p. 71.

Teachers have many problems to solve, real problems, and perplexing ones. Many of them can be partially if not wholly solved by means of investigation requiring more time than the teacher can afford, however in scores of actual cases, by means of informal investigation a solution, although not ideal, has helped remove the existing difficulties.

Since pupils do not learn with equal facility nor at equal rates, there must be provision for individual differences.

> Effective instruction cannot be guaranteed by any single simple formula, it goes without saying that, if instruction is to be really effective, the subject matter must be selected and organized in such a way as to make it appropriate and suited to the age and must be presented in an understandable and interesting way, and there must be provision for ample practice. Skills and concepts once developed must be maintained through reapplication and not allowed to deteriorate through disuse. 4

These considerations involve careful planning and adequate testing of outcomes. Testing has been in use as long as education has existed, but it has been used in the schools primarily as a means for assigning marks. Only in recent years has there come a general recognition that the use of test may be used not to measure the results of instruction but also to improve instruction, and there is a widespread and growing feeling that this, after all, should be regarded as the most important service which they can render.

The number of slow pupils entering the ninth grade has been increasing year by year and the percentage of failures in ninth year algebra classes has been steadily rising.

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4. Ibid., p. 132.

> Compulsory education laws have tended to bring into the schools all levels of mental ability. This has added to the work of the teacher and increased the need for thorough professional training....Ability grouping has become the regular policy of many school systems and, even where this is not possible, the pupils are urged to progress at their own speed. 5

The waste in these failures and in the increasing number of repeaters in algebra give clear indication of the need for a real solution of the problem.

There was a feeling that since these pupils could not successfully do the work in algebra, they must have special aptitude in work requiring manual dexterity. Hence it became customary to transfer them from algebra to pure or practical art courses. For a while this was considered a partial solution. It relieved the situation in the algebra classes and made it possible to give more attention to the interest of the more rapid learning pupil. Unfortunately there were three circumstances which militated against the success of the plan.

1. The slow pupil was frequently failing in other academic subjects besides algebra.
2. Shop, art, and home-economics teachers denied any superioity of the slow pupil in their work.
3. It was apparent that this attempted solution failed to give weight to the needs of the slow pupil.

In mathematics several plans were tried and discarded for one reason or another. These were: lower passing standards in algebra, elimination of difficult material, the contract plan, and a slower pace. None of these offered a solution that was satisfactory in all respects. All were based on a modification only of the courses in algebra and hence failed to provide for the needs of the slow pupils.

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5. Ibid., p. 227

At the same time, as so far as a plan provided slower, more deliberate teaching of algebra for the slow learning pupil, it failed to provide for the pace of the more rapid learner. For this reason it was decided to form special classes for the slow group. It was felt that thus the bright pupil would no longer be compelled to waste time while the slower pupil received the painstaking instruction he needed. On the other hand it was evident that the slow learning pupil could study topics in mathematics more withing his needs, interest, and abilities than he could if he studied the mathematics that the college preparatory course offered. 6

Individual instruction is, of course, the ideal method of aiding the slow or giving the brilliant student the benefit of our past experiences, however the impossibility of this is obvious and the next best thing is to divide same age groups into somewhat similar mental groups.

In grouping within grades we reach the most accurate adjustment to the needs of pupils short of individual instruction.

It is the last out of classification of the part of administrator and in it the teacher's function likewise becomes prominent. The teacher is entitled to the benefits of segregration, regrading, and grouping within grades and should work to support these measure. For by them the teacher's task of reaching the individual is reduced to workable dimentions. 7

Regrouping a class of individuals must of necessity take into consideration the differences in intelligence, achievement and aptitudes.

There are important and significant differences among individuals relative to their achievement in the subject. As indicated these differences are often, if indeed not primarily, due to differences with mathematical material especially organized for slow pupils have shown that these individual can learn some mathematics. 8

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6. Virgil S. Mallory, Teachers College Contributions To Education, (New York: Columbia University Press, 1939), p. 1.
7. John C. Almack, Research and Thesis Writing, (Boston: Houghton Mifflin Company, 1930) p. 293.
8. Harry E. Benze, Joint Yearbook American Education Research Association and the Department of Classroom Teachers, Secondary Mathematics, (Washington D.C.: National Education Association, February, 1939), p. 204.

If mathematics is to make its full contribution in the attainment of such objectives as those outlined under this present-day educational philosophy, teachers of mathematics will have to arouse themselves from a static satisfaction in the historical perfection of their subject to a dynamic realization of the need for the formulation of its content into units of instruction that are vital and timely in their signifigance.

> Teachers of mathematics are under particular temptation to succumb to this lure of presentation of facts for their own sake. This is because a mathematical fact, at least one of the kind commonly taught in schools, has a peculiar quality of respectability.....In addition to this danger, teachers of mathematics also face a peculiar opportunity. When they accept the purpose of a genuinely social education and work wholeheartedly toward the achievement of that purpose, they find in their subject an instrument of great educational utility. They can teach mathematics for direct application. To a wide variety of practical problems and for indirect application to countless others. They can employ it to direct the careful thinking in social situations upon which a good society must be based. When they meet this opportunity intelligently, they find their subject expanding and growing more valuable with every practical educational use. 9

The general movement of introducing a course for freshmen mathematic pupils in which the objective is socialized and not very specific has proven too confusing to not warrant some sort of investigation.

> As a result of the general mathematics movement in the junior high school we find that the mathematics courses have been changed from the formal compartmental arrangement to studies with concrete beginnings, less scientific rigor, more development, more provisions for individual differences,

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9. Op. Cit., Butler and Wren, p. 27.

and better fusion of related topics. This effort to present the mathematics of the junior high school in a fused course has not been without its rather severe critics. There are those who feel that it is too much of a hodgepodge of superficialities that tends to general weakening of the subject content. 10

The scientific method is universally employed in the research process. It follows a systemtic plan, beginning with hypothesis, and passing in order to the collection of facts, the classification of facts, and generalization from facts.

> The observations of which science is made must be valid and objective. Valid observations are authentic, true; they are what they purport to be. Reliable observations are accurate, without significant error. Validity is established by proof that the sources of the data are genuine, and, if measurement and counting are employed, that these genuine sources have been used. Reliability is dependent chiefly upon four factors; objectivity, a limited field, accurate enumeration and measurement, and careful records. 11

Certain procedures of investigation are sometimes given the status of independent methods. Among these are the case study, the genetic, the comparative, the survey, the summary, and the device known as the questionaire.

> A critical examination of the minor methods enumerated shows whether they are inadequate as methods of inductive science, or that they are identical with one of the standard method, historical, experimental, and normative--particularly the last. As independent methods they do not result in generalization; they tend rather to go from the general to the particular. The questionaire has a useful foundation in applied studies, but is is very limited in value as a vehicle of research. The probabilities are so great that the results will prove inadequate and unreliable that it should be avoided in thesis making, except as a last resort.12

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10. Ibid., p. 29.
11. Op. Cit., Almack, p. 83
12. Ibid., p. 83.

The statistical method of scientific procedure in research is founded upon the concept of individual differences.

> It takes things as they are and classifies them to make them yield desired information, whereas the experimental method employs the artificial control of things to discover the truth about them. Consequently, the statistical method is especially good as a substitute for the experimental method on such problems as do not permit of controlled conditions. It is based on sampling. Hardly ever does the statistician have data on all cases which he is studying. He usually works with facts about a selected few which are known or supposed to be a typical sampling from the total group. He observes this sampling and derives from it some kind of statistical formula for predicting how the whole mass would also behave. It looks to what is common rather than to what is unique. It seeks to derive from a number of cases a general rule, law, or formula which expresses a universal relationship that holds true for all cases of the kind. 13

> It has been said that "figures can't lie but liars can figure." Also that there are three kinds of liars, "Liars, damn liars, and statisticians."....Calculations are not ends in themselves but amateurs sometimes delight in making them so, much as a small boy delights in whittling with his first pocket knife. Each calculation that is made should be made for a definite purpose, clearly seen before hand....Someone has suggested that the statistician should beware of letting his mathematics smother his common sense. That is, he should check his work for its logical soundness as well as for its technical accuracy. Formulas and figures are fine as far as they go, but they do not go the whole way. 14

THE SPECIFIC PROBLEM--A representative group of pupils were selected from a class of one hundred freshman in Tigard Union High School, Tigard, Oregon. This selection was of necessity made from pupils in the writer's own classes because of a disruption in their schedules if any other method of selection was used.

13. Claude C. Crawford, The Technique of Research in Education, (Los Angeles;The University of Southern California Press, 1928) p. 17
14. Ibid., p. 18.

used.

THE METHOD--The students registering in the fall were grouped into three groups according to IQ's based on the Otis Self-Administrating Test., and assigned to English classes accordingly. This might seem that they would naturally fall into other classes the same way but by examining the list it was found that they were mixed as if they had never been separated.

In checking the list of students who fell into the testing program of the researcher, fifty students were divided as follows: Seventeen from the high and low and sixteen from the average or normal of the class. The group tested, therefore, was a nearly representative of the class as was possible.

TESTS AND THEIR VALIDITIES--Otis Classification Test, revised, is the Beta test of the Otis Quick-Scoring Mental Ability Tests, and is furnished in three alternative forms, R, S, and T. The form used in the case of this study was form R.

> A comparison was made between the Mental Ability Test of the original Classification Test and the National Intelligence Tests and Haggarty Intelligence Examination; Delta s, from the scores of 286 pupils in Grades 4 to 8. The correlation between the National Intelligence Tests and the Mental Ability Test was .889, the correlation between the National Intelligence Tests and Delta 2 was .926, and the correlation between the Mental Ability Test and Delta 2 was .927. The amount and approximate equality of these correlations suggest that the three tests measure approximately the same ability with approximately the same degree of validity. 15

Traxler Silent Reading Test is in four forms, three of which are published. The three published forms are adapted for machine

15. Arthur S. Otis, Manual of Directions, Otis Classification test, (New York: Yonkers-on-Hudson, 1941), p. 3.

scoring with special answer sheets.

> The validity of test scores appears adequate... Comprehension validity (story comprehension plus power of comprehension) with a composite crieterion score was found to be .80... When compared with school marks the total score has a validity of .56. Analysis of individual items revealed positive validity of all. 16

The Foust-Schorling Test of Functional Thinking in Mathematics appears in two forms-A and B. Form A was used in the case study presented. The proof of the validity of these tests was not given in the manuals but comparison between mental ability and mathematical functional thinking was made by the originators of the test in their manual of directions.

> Scores on this test of mathematical relationships correlate rather highly with scores on a well-known intelligence test. The correlation is .66 between scores on Form A of the Foust-Schorling Test of Functional Thinking in Mathematics and Form C of the Terman-McNemar Test of Mental Ability for 22 pupils in Grade 10 of the national standardization population for the former test. There is also a substantial correlation, .53, with scores on the Schorling-Clark-Porter Hundred Problem Arithmetic Test for all tenth graders in the same nationsl standarization population. 17

The MacQuarrie Test for Mechanical Ability is a battery of seven subtest providing objective measurement of the aptitudes which underlie successful performance of a wise variety of jobs of a mechanical nature.

The reliability of the test is reported as high, and,

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16. Oscar Crisen Buros, The Nineteen Forty Mental Measurements Yearbook, (Highland Park, New Jersey: The Mental Measurement Yearbook, 1941.) p. 1581.
17. Judson W. Foust and Raleigh Schorling, Manual of Directions for Foust-Schorling Test of Functional Thinking in Mathematics, (New York; Yonkers-on-Hudson, 1944), p. 4.

under favorable conditions, a validity as high as .80 has been reported. 18

The Test for Scientific Background was made up of a group of miscellaneous statements, fifty in all, from the fields of science in which students should have some basic knowledge from grade school instruction and every day observation.

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18. Walter D. Scott, Robert C. Clothier, Personnel Management, (New York: McGraw-Hill Book Company, Inc., 1941) p. 381

CHAPTER TWO

Correlation of Mathematical Functional Thinking with Intelligence, Reading Comprehension, Scientific Background, and Mechanical Ability

The fluctuations in a given series are seldom dependent upon a single factor or cause. The measurement of the association between such a series and several of the variables causing these fluctuations or associated with the dependent variable is known as multiple correlation.

> Multiple correlation consists of the measurement of the relationship or association between a dependent variable and two or more independent variables. The procedure is similar to that for simple correlation with the exception that other variables are added to the regression equation. 1

The purposes of multiple correlation is to determine what correlation would result if two or more scores were weighted in the most favorable proportions possible and this composite score correlated with some third score, or criterion. For example:

> The investigator wished to predict success in algebra. He has already correlated intelligence with algebra grades, getting a coefficient of say .54. He has correlated arithmetic and algebra grades, getting a coefficient of say .68. The correlation between arithmetic grades and intelligence he has found to be, say .37. His problem then is whether a weighting of the arithmetic grades and the intelligence scores in the most favorable manner possible would result in a better correlation than arithmetic alone gave. 2

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1. Herbert Arkin and Raymond R. Colton, Statistical Methods, (New York; Barnes and Noble, Incorporated, 1939), p. 94
2. Op. Cit., Crawford, p. 233.

The chart given is the result of tabulating the various scores made, by fifty students, fourteen years of age, registered in the Tigard Union High School, Tigard, Oregon, in tests to measure the relationship between mathematical functional thinking, intelligence, reading comprehension, scientific background and mechanical ability. By converting all of the product sums of Table II, Appendix A, into deviations from the different means the labor of computation is materially lightened.

> This is because any straight line fitted by the method of least squares always passes through the means of the series and therefore as in the estimating equation becomes zero; and since there is one less constant to find, there is one less normal equation. 3

To put the matter concretely, in our present problem the value of the product moment may be computed from:

$$p_{12} = \frac{\Sigma(X_1X_2)}{N} - \frac{\Sigma(X_2)}{N} \cdot \frac{\Sigma(X_2)}{N} \qquad (4)$$

The "normal" equations will now read:

$$p_{12} = b_{12.34}\,\sigma_2^2 + b_{13.24}\,p_{23} + b_{14.23}\,p_{24} \qquad (1)$$

$$p_{13} = b_{12.34}\,p_{23} + b_{13.24}\,\sigma_3^2 + b_{14.23}\,p_{34} \qquad (2)$$

$$p_{14} = b_{12.34}\,p_{24} + b_{13.24}\,p_{34} + b_{14.23}\,\sigma_4^2 \qquad (3)$$

Thus the value of b may be obtained by solving the three equations simultaneously.

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3. Op. Cit., Crawford, p. 238.

These equations may be simplified by assuming the origin to be at the point of averages and dividing both sides of the equation by N. 4

The Standard deviation may be obtained by the following formula;

$$\sigma x = \sqrt{\frac{x^2}{N} - \frac{x}{N}^2} \qquad (5)$$

5

The coefficient of multiple correlation is computed by the following formula;

$$R^2_{1.234} = \frac{b_{12.34}\, p_{12} + b_{13.24}\, p_{13}}{\sigma_1^2} \qquad (6)$$

5

Details of solution will be explained in the following chapter.

It is not uncommon for two variables to be correlated with each other simply because each is dependent upon some third variable. For example:

> If we should find a correlation between a student's notes and his grades, we would not know whether the notes affected the grades or whether good notes and good grades were both due to high intelligence. The device by which we can answer this question is called partial correlation. It seeks to find what the correlation between two variables would be if the effect of a third one were held constant.

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4. Op. Cit., Arkin and Colton, p. 218.
5. Ibid., pp. 218, 219.

> Thus partial correlation serves somewhat the same purpose in statistical work as controlling conditions to hold all variables constant except the one to be studied plays in experimental work. The experiment would not allow these other variables to enter into the situation. The statistical study lets them operate as they will, and then discounts their influence by means of partial correlation. 6

The coefficient of partial correlation is a measure of the relationship between the dependent variable and one independent variable, when the influence of the other independent variable (or variables) has theoretically been removed from both.

The purpose of these coefficients is to show the relative importance of the different independent variables in explaining variations in the dependent variable. This is done by finding the extent to which correlation is increased by the addition of another constant. More precisely, it may be said that the coefficient of partial determination (the square of the coefficient of partial correlation) is the ratio between the increase in the variation of the computed values of the dependent variable resulting from introducing another independent variable (that is, the net variation associated with that factor), and the variation that had not been explained before the introduction of the new factor.

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6. Op. Cit., Crawford p. 231.

"The denominator of this ratio may also be regarded as the total variation which the new variable seeks to explain." 7

7. Frederick E. Croxton, and Dudley J. Cowden, Applied General Statistics, (New York: Prentice-Hall, Inc. 1942), p. 742, 743.

SUMS AND MEANS

$\Sigma X_1 = 2545$	$\Sigma X_2 = 5458.3$	$\Sigma X_3 = 3334$	$\Sigma X_4 = 3012$	$\Sigma X_5 = 2779$
$\bar{X}_1 = 50.9$	$\bar{X}_2 = 107.2$	$\bar{X}_3 = 66.7$	$\bar{X}_4 = 603$	$\bar{X}_5 = 55.58$

Product Sums, Correction Factors and Deviation Product Sums

$\Sigma X_1^2 = 171159$	$\Sigma X_1X_2 = 288090$	$\Sigma X_1X_3 = 181783$	$\Sigma X_1X_4 = 168818$	$\Sigma X_1X_5 = 149058$
$\bar{X}\Sigma X_1 = 129541$	$\bar{X}_2\Sigma X_1 = 272722$	$\bar{X}_3\Sigma X_1 = 168700.6$	$\bar{X}_4\Sigma X_1 = 153311$	$\bar{X}_5\Sigma X_1 = 141451$
$\Sigma x_1^2 = 41608.5$	$\Sigma x_1x_2 = 15367.8$	$\Sigma x_1x_3 = 12082.4$	$\Sigma x_1x_4 = 15507.2$	$\Sigma x_1x_5 = 7606.9$
	$\Sigma X_2^2 = 571688$	$\Sigma X_2X_3 = 366900$	$\Sigma X_2X_4 = 326564$	$\Sigma X_2X_5 = 298068$
	$\bar{X}_2\Sigma X_2 = 574103.3$	$\bar{X}_2\Sigma X_3 = 357271.5$	$\bar{X}_2\Sigma X_4 = 322765.93$	$\bar{X}_2\Sigma X_5 = 297797.64$
	$\Sigma x_2^2 = 2415.28$	$\Sigma x_2x_3 = 9628.56$	$\Sigma x_2x_4 = 3798.1$	$\Sigma x_2x_5 = 260.36$
		$\Sigma X_3^2 = 229607$	$\Sigma X_3X_4 = 200840.2$	$\Sigma X_3X_5 = 181899$
		$\bar{X}_3\Sigma X_3 = 2234444$	$\bar{X}_3\Sigma X_4 = 2051188$	$\bar{X}_3\Sigma X_5 = 185303.7$
		$\Sigma x_3^2 = 6252.88$	$\Sigma x_3x_4 = 4347.84$	$\Sigma x_3x_5 = 3404.72$
			$\Sigma X_4 = 190786$	$\Sigma X_4X_5 = 167406.96$
			$\bar{X}_4\Sigma X_4 = 181442.88$	$\bar{X}_4\Sigma X_5 = 164371$
			$\Sigma x_4^2 = 9343.12$	$\Sigma x_4x_5 = 935.96$
				$\Sigma X_5^2 = 1625.3$
				$\bar{X}\Sigma X_5^2 = 154416.82$
				$\Sigma x_5^2 = 8096.18$

CHAPTER THREE

Computation

Because the investigation is being made for the purpose of finding out what constitutes mathematical ability in order to segregate certain groups, the dependent variables will be the results of the mathematical functional thinking test. The independent variables being intelligence, reading comprehension and scientific background. Because of the fact that more variables than three tend to lessen the reliability of the result, the researcher has decided to correlate the final test, mechanical ability, only, with the mathematical functional thinking test.

The standard deviation and probable error of each variable were computed first in order to have these figures when needed in computing multiple and partial correlation.

All formulae are taken from Crowden and Croxton, Applied General Statistics. To find the standard deviation (σ) reference is made to figures already computed in Chart I, page 16. X1 is the test for mathematical ability, X_2 the intelligence test, X_3 reading comprehension, X_4 scientific background, and X_5 the mechanical ability test. N is the number of cases.

Using formula (5) :

$$\sigma 1 = \sqrt{\frac{171159}{50} - \frac{2545}{50}^{2}}$$

$$\sigma 1 = 18.62$$

$$\sigma 2 = \sqrt{\frac{571688}{50} - \left(\frac{5358}{50}\right)^2}$$

$$\sigma 2 = 10.69$$

$$\sigma 3 = \sqrt{\frac{229697}{50} - \left(\frac{3334}{50}\right)^2}$$

$$\sigma 3 = 7.8$$

$$\sigma 4 = \sqrt{\frac{190786}{50} - \left(\frac{3012}{50}\right)^2}$$

$$\sigma 4 = 16.63$$

$$\sigma 5 = \sqrt{\frac{162513}{50} - \left(\frac{2779}{50}\right)^2}$$

$$\sigma 5 = 7.079$$

The P. E. or probable error is computed by multiply the σ by .6745.

P.E.X_1 is 12.54

P.E.X_2 is 9.088

P.E.X_3 is 5.26

P.E.X_4 is 11.32

P.E.X_5 is 5.778

The formula to find the Multiple Correlation is

$$R_{1.234} = \sqrt{\frac{b_{12.34}\, p12 + b_{13.24}\, p13 + b_{14.23}\, p14}{\sigma 1^2}} \qquad (3)$$

The term $b_{12.34}$ is an estimate of variation in which the sub numbers preceeding the decimal point represents the variable of those numerals. When the other factors of the numbers following the decimal are held constant. This is known as holding some "variables constant statistically, rather than experimentally." 1 p12 etc. is the product moment of the two variables of the subnumeral. (4) Other product moments are found by substituting values of each variable respectively. So computing by logarithms the following results were obtained.

$$p_{12} = \frac{288090}{50} - \frac{2545}{50} \cdot \frac{5358}{50}$$

$$p_{12} = \underline{307.356}$$

$$p_{13} = \frac{181783}{50} - \frac{2545}{50} \cdot \frac{3334}{50}$$

$$p_{13} = \underline{241.588}$$

$$p_{14} = \frac{168818}{50} - \frac{2545}{50} \cdot \frac{3012}{50}$$

$$p_{14} = \underline{3101.144}$$

$$p_{23} = \frac{366900}{50} - \frac{5358}{50} \cdot \frac{3334}{50}$$

$$p_{23} = \underline{192.55}$$

$$p_{24} = \frac{326564}{50} - \frac{5358}{50} \cdot \frac{3012}{50}$$

$$p_{24} = \underline{75.9616}$$

$$p_{34} = \frac{305188}{50} - \frac{3334}{50} \cdot \frac{3012}{50}$$

$$p_{34} = \underline{86.96}$$

By solving the following equations simultaneously we can find the values of $b_{12.34}$; $b_{13.24}$; $b_{14.23}$

$$p_{12} \quad b_{12.34}\,\sigma_2^2 + b_{13.24}\,p_{23} + b_{14.23}\,p_{24} \qquad (7)$$

$$p_{13} \quad b_{12.34}\,p_{23} + b_{13.24}\,\sigma_3^2 + b_{14.23}\,p_{34} \qquad (8)$$

$$p_{14} \quad b_{12.34}\,p_{24} + b_{13.24}\,p_{34} + b_{14.23}\,\sigma_4^2 \qquad (9)$$

To avoid confusion we will use the unknown $x = b_{12.34}$; $y = b_{13.24}$; $z = b_{14.23}$.

I $\quad 307.4 = 48.3\,x + 192.6\,y + 76\,z$

II $\quad 241.6 = 196.6\,x + 105\,y + 87\,z$

III $\quad 310.00 = 76\,x + 87\,y + 187\,z$

First equation we may eliminate x by multiplying by 192.6 and equation number II by 48.3. By working with logs this saves a good deal of calculations and the values found are:

$$b_{12.34} = \underline{.1463}$$

$$b_{13.24} = \underline{1.354}$$

$$b_{14.23} = \underline{.3958}$$

Using these values we are now ready to compute $R_{1.234}$, or

multiple correlation. Using formula (6)

$$R_{1.234} = \frac{(.1463)\ (307.35)+(1.354)\ (241.59)+(.3958)\ (310.25)}{344.71}$$

$$R_{1.234} = \underline{.7711}$$

This is some indication that the four factors used have some correlation and if we should eliminate the fourth factor or scientific background a multiple correlation would only be:

$$R_{1.23} = \frac{x^2_{c\ 1.23}}{x^2_1} \qquad (10)$$

$$R_{1.23} = \underline{.5708}$$

If each factor is correlated with the constant factor (mathematical ability) each added factor tends to increase the correlation. Thus we see by partial correlation:

$$_{12}r^2_{34} = \frac{b^2_{12.34}\ \sigma_2^2}{b^2_{12.34}\ \sigma_2^2\ \ \sigma_1^2\ \ (1-R^2_{1.234})} \qquad (11)$$

$$_{12}r^2_{34} = \underline{.3384}$$

By using formula (11) and correlating the different independent variables with the mathematical functional thinking we have the following results.

$$_{13}r^2_{24} = \underline{.3609}$$

$$_{14}r^2_{23} = \underline{.5458}$$

CHAPTER FOUR

Conclusion

Perhaps the reader will be surprised to find a coefficient of multiple correlation of only .7711 and coefficient of partial correlation of plus .3384, .3609, and .5458.

> It is not characteristic of these types of measures that the multiple coefficient is the sum of the two or more partial correlation.
>
> It is always the case that, as more pertinent variables are introduced, the standard error of estimate becomes smaller, and the coefficient of multiple correlation larger. [1]
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> .....
>
> The customary procedure in education research for determinating whether or not an observed r is significant has been to compute the standard error of r, <u>infra</u>, and to describe the coefficient as significant if it is more than 2.5 or 3 times the standard error. The formula used for σr is :
>
> $$\sigma r = \sqrt{\frac{1-r^2}{N}} \qquad (12)$$
>
> [1]

However, according to Lindquist a more accurate check upon the value of minimum r can be computed from the table given on page 212 in his book. According to his table the ${}_{12}r_{34}$ or .3384 for fifty cases is significant because at the 5% level the essential r must be .279 or .361 at 1% level. ${}_{13}r_{24}$ would also be significant as is ${}_{14}r_{23}$.

---

1. Everet Lindquist, <u>Statistical Analysis in Educational Research</u>, (Boston; Houghton-Mifflin, 1940), p. 210.

However after computing the r of X_1 and X_5 and finding a correlation of only .1239, we can conclude that correlation between mathematical functional thinking and mechanical ability is not important.

We can not make too positive statements about the influence of the other factor upon one another because many possibilities can be analyzed and taken into consideration. The prediction can only be an estimate of what is true of these particular pupils.

> The interpretation of partial correlation coefficients has caused considerable difficulty in educational research. It should be recalled particularly that a correlation coefficient tells nothing whatever about the nature of the cause and effect connections between variables. The fact that r AB is not equal to 0 may mean that A is in part caused by the other, or that both are in part caused by other and unspecified variables. The correlation coefficients in itself provides no clue whatever as to which of these is the correct explanation. The same is true of partial correlation coefficients.
>
> .....
>
> Suppose, for example, that we compute r abc for a group in which A represents the score on a reading test, B that on an arithmetic test, and C that on a general intelligence test. In the first place, we must recognize that the factor which is held constant is only the <u>score</u> on the intelligence test. Because of the unreliability in whatever the test measure. In the second place, none of the scores, is a <u>Pure</u> or perfectly valid measure, even aside from chance errors in measurement, of the ability implied in the title of the test, but is partly a measure of many irrelevant factors which may or may not influence the scores on the other tests as well. In the third place, a good measure of general intelligence is in part a measure of arithmetic ability and of some of the factors involved in reading. In "holding constant" intelligence we may therefore be holding constant more than we should. In the fourth place, we are rarely able to provide a very meaningful and exact description of what each test is intended to

measure, to say nothing of what it actually does measure. In the fifth place the observed r abc is subject to sampling errors, and may be very markedly influenced by chance fluctuations in the zero order r's. In fact, partial R's cannot possibly be very meaningful unless computed from much larger samples than have usually been employed for this purpose in educational research. Finally, there are many other factors, in addition to those measured by general intelligence test, which might in part account for the correlation between the scores on the arithmetic and reading test, and which have not been held constant in this analysis. Under all of these conditions, it would be foodhardy indeed to attempt to say much, on the basis of partial correlation, about the cause-and-effect relationships between the traits implied in the test title. 2

It is apparent that a pupil with high intelligence, good reading comprehension and a scientific background will probably be more successful in a course of mathematics in which functional thinking is stressed than one who has no ability in these aptitudes.

In this area it has been demonstrated that problem-solving ability is so closely related to reading comprehension that it is quite safe to assert that considerable improvement will be made in the ability in question by improving the reading comprehension of the pupil. 3

.....

Mathematical success in the ninth grade has been predicted by marks in arithmetic, averages of all school grades, intelligence, and special prognosis tests, to the extent represented by correlation of .40-.90. Much was expected of certain special prognostic tests which have been developed from time to time, but these tests have been somewhat disappointing. Their failure to predict achievement more reliably has no doubt been due in large part to the presence of a variety of other factors which condition achievement. They predict best when combined with other measures in a multiple correlation technic. 4

Probably one who is guiding pupils of this school in the future might study these abilities before pupils are placed in a

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2. Ibid., p. 251.
3. Op. Cit., Lindquist, p. 204.
4. Ibid., p. 205.

general mathematics course. Thus placing the more intelligent, better readers, and those of good scientific background in a course that will stress more thinking development and problems of material significance. This might help develop the power to see spacial relations, recognize the relationships between varying quantities, interpret a mathematical statement or expression of dependence by telling just how the one quantity depends upon the other and ability to express such relationships in mathematical language or symbols.

> Tests of mental ability may, than, be used to great advantage in improving grade and section placement. ... The less intelligent children should not be advised to take college preparatory work; the gifted children should be especially urged to obtain such an advanced education. In the junior high school these children should be given work in practical manual training or in the domestic arts. It has been found that such guidance tends to cut down the number of failures by keeping the duller children away from such subjects as Latin and algebra, in which they would be likely to fail; it holds the children in school, and off the streets, longer because they are given work they can do, and keeps such children contented and happy in their school work so they remain in the school atmosphere during the important period of adolesence. 5

5. Sidney L. Pressey and Luella Pressey, Introduction to Use Standard Test, (New York : World Book Company, 1922), p. 176.

APPENDIX A

TABLE I

COMPUTATION OF PRODUCT SUMS REQUIRED FOR MEASURES OF RELATIONSHIP BETWEEN MATHEMATICAL FUNCTIONAL THINKING ABILITY, INTELLIGENCE, READING COMPREHENSION, SCIENTIFIC BACKGROUND, AND MECHANICAL ABILITY OF 50 TIGARD HIGH SCHOOL FRESHMAN

Student	Mathematical Functional Thinking Ability	Intelligence	Reading Comprehension	Scientific Background	Mechanical Ability
	X_1	X_2	X_3	X_4	X_5
1	64	102	71	56	53
2	77	107	65	64	44
3	15	102	69	48	61
4	23	99	49	50	39
5	77	101	71	56	67
6	37	108	67	66	48
7	87	113	63	68	69
8	85	110	68	68	62
9	83	114	65	90	54
10	60	105	74	46	66
11	48	109	68	50	49
12	80	124	75	70	46
13	66	118	68	42	49
14	18	112	74	50	46
15	45	109	76	48	49
16	56	112	73	60	53
17	45	122	77	80	62
18	85	112	77	64	66
19	74	110	81	66	95
20	96	126	74	80	22
21	83	126	88	88	69
22	45	116	64	70	60

TABLE I (continued)

Student	X_1	X_2	X_3	X_4	X_5
23	91	126	73	72	63
24	32	117	81	86	52
25	52	118	80	88	58
26	98	128	72	42	42
27	15	108	52	66	59
28	32	130	77	38	52
29	18	84	33	54	63
30	71	86	59	72	67
31	64	115	76	58	57
32	15	109	47	52	45
33	32	66	65	69	32
34	15	86	47	38	61
35	45	85	46	69	43
36	41	95	56	38	53
37	41	100	55	68	62
38	94	98	57	59	40
39	32	107	62	64	68
40	32	98	71	52	67
41	41	100	59	78	60
42	83	96	64	34	47
43	18	83	34	79	90
44	74	120	88	70	60
45	43	100	53	42	54
46	47	115	76	52	49
47	69	119	71	66	69
48	55	114	80	54	60

TABLE I (continued)

Student	X_1	X_2	X_3	X_4	X_5
49	11	108	66	48	47
50	74	104	80	65	47
Total	2545	5358	3334	3012	2779

TABLE II

Student	X_1^2	X_1X_2	X_1X_3	X_1X_4	X_1X_5
1	4906	6528	4544	3584	3392
2	5929	8329	5005	4928	3388
3	225	1530	1035	7200	915
4	5929	2277	1127	1150	997
5	7569	7777	5467	4212	5159
6	7569	3996	2470	2442	1776
7	7225	9831	5481	5916	5220
8	6889	9350	5780	5780	6170
9	3699	9462	5395	7370	4482
10	2394	6300	4440	2760	3960
11	6499	5332	3264	2400	2353
12	36	9920	7600	5600	3680
13	324	608	408	252	294
14	2025	2016	1492	9000	8828
15	3136	4895	3490	2160	2655
16	2025	6372	4088	3360	2968
17	7225	5040	3465	3600	2385
18	5476	9869	6545	5440	5279
19	9206	8288	5994	4884	4884
20	6889	11712	7104	7680	9120
21	2025	9130	7304	7704	1826
22	8281	5670	2880	3150	2700
23	1024	11466	6643	6552	5733
24	5929	3644	2593	1920	1664
25	2704	12544	4169	4472	3016
26	9604	1620	7056	8624	4116
27	225	1620	780	630	885

TABLE II (continued)

Student	X_1^2	X_1X_2	X_1X_3	X_1X_4	X_1X_5
28	1024	4160	2460	630	1664
29	342	1512	594	684	1134
30	5041	6106	4189	4834	4757
31	4096	7360	4864	4698	3648
32	225	1635	795	870	675
33	1024	2112	1480	1664	7736
34	225	3725	705	900	915
35	2025	3825	2070	1710	2880
36	1681	3785	2296	2469	1763
37	8836	4100	2255	1804	2173
38	1024	3424	1985	6392	5828
39	1681	3136	1984	1600	2180
40	6889	4100	2272	2048	2186
41	423	7968	2419	1132	2047
42	5476	1494	5312	6474	4150
43	1849	8880	612	612	846
44	2209	4300	6412	5180	6660
45	3600	5305	7220	1806	2580
46	3025	7140	3572	2444	2518
47	121	6370	4560	3960	2940
48	5476	4324	9305	2970	3795
49	1024	7696	880	528	660
50	1691	1188	4884	4736	3488
Total	171159	288090	181783	168818	149058

TABLE III

Student	X_2^2	X_2X_3	X_2X_4	X_2X_5
1	10404	7242	5712	5406
2	11449	6955	6828	4708
3	10404	7038	4896	6222
4	9801	9351	4950	3861
5	10201	7171	5656	6767
6	11664	7236	7128	5184
7	21769	7119	7684	6780
8	12100	7480	7489	6820
9	12996	7510	9269	6156
10	11025	7770	4839	6939
11	11881	7412	5459	5341
12	15476	9300	8689	3470
13	13924	8024	4956	4782
14	12554	8488	6599	5152
15	11881	8284	5232	6431
16	12544	8176	6689	5936
17	12544	8624	8960	5936
18	13456	8932	7424	7192
19	12544	9072	7392	9549
20	14884	9028	9769	2420
21	12100	9680	9680	7560
22	15876	8064	8820	7938
23	15876	9098	9072	6084
24	13689	9477	7020	6844
25	13924	9440	10148	5376
26	16384	5716	11264	5376
27	11664	9216	4536	6372
28				

TABLE III (continued)

Student	X_2^2	X_2X_3	X_2X_4	X_2X_5
28	16900	10010	8580	6700
29	70567	22772	3192	5272
30	7396	55074	4644	5762
31	13225	5740	8280	6555
32	11181	5123	6322	4905
33	4356	4320	3432	1418
34	77396	4042	3160	5256
35	7225	3910	3210	5440
36	9025	5320	5700	4085
37	10000	5500	4400	5300
38	9604	5684	6664	6076
39	11449	6623	5350	4280
40	9604	6958	6272	6664
41	10000	5900	5600	6700
42	9216	6144	7488	4801
43	6889	6822	2822	3901
44	14400	9560	8400	9800
45	10000	5300	4299	6000
46	13225	5740	5980	6215
47	141461	8044	7154	5831
48	12996	8094	6156	7866
49	11664	8094	5184	6589
50	10816	8640	6656	4888
Total	571688	366900	326564	298088

TABLE IV

Student	X_3^2	X_3X_4	X_3X_5
1	5041	3976	3763
2	4225	4169	2860
3	4761	3312	4209
4	2401	2450	1011
5	5041	3950	4757
6	4489	3076	3216
7	3969	4422	3789
8	4225	4284	4216
9	5476	4624	3510
10	4624	5850	4888
11	5625	3404	3332
12	4624	3400	3404
13	4576	5250	4484
14	5776	2856	3859
15	5329	3700	4081
16	5020	3648	4774
17	5020	4380	5346
18	6561	6160	7030
19	5376	4928	1936
20	7754	5346	3840
21	4096	5920	4599
22	5329	7754	4202
23	6561	4480	4640
24	6400	5256	2024
25	5161	4860	3068
26	6200	6880	3780
27	5184	6236	3510
	2704	34	

TABLE IV (continued)

Student	X_3^2	X_3X_4	X_3X_5
28	5929	5082	4004
29	1089	1254	2079
30	3481	3186	3953
31	5776	5472	4332
32	2209	2724	2115
33	4225	3380	1495
34	2209	2820	2867
35	2116	1748	2844
36	3136	3360	2408
37	3025	2420	4828
38	3364	3944	3953
39	3844	3100	3200
40	5041	4544	1598
41	3481	3068	7920
42	4096	4992	3180
43	1156	1156	4104
44	7744	6160	7920
45	2809	2260	3180
46	5776	3952	4104
47	5776	5016	3724
48	5041	3824	4899
49	6400	3840	2880
50	4356	4224	2008
Total	229697	205188	18199

TABLE V

Student	X_4^2	X_4X_5
1	3136	2968
2	4096	2816
3	2304	2928
4	2500	1959
5	3136	3725
6	4356	3168
7	4624	4980
8	2624	4456
9	8100	4869
10	2116	3136
11	2500	2459
12	4900	3229
13	1764	3958
14	2500	2399
15	2304	2837
16	3600	3180
17	6400	4249
18	2096	3968
19	4356	4356
20	6400	7699
21	7744	1936
22	4900	4299
23	5184	4536
24	3600	3120
25	7396	4988
26	7755	3696
27	1764	2478

TABLE V (continued)

Student	X_4^2	X_4X_5
29	1444	2394
30	2916	3618
31	5184	4104
32	3364	2610
33	2704	1196
34	3600	3660
35	1444	2432
36	3600	2580
37	1936	2332
38	4624	4216
39	2500	2000
40	4096	4352
41	2704	2284
42	6084	3900
43	1156	1598
44	4900	6300
45	1764	2520
46	2704	2808
47	4356	2234
48	2916	3726
49	2304	2880
50	9042	3008
Total	190786	164371

TABLE VI

Student	X_5^2
1	2809
2	1936
3	3721
4	1521
5	4489
6	2304
7	3600
8	3844
9	2916
10	4356
11	2401
12	2116
13	2401
14	2116
15	3481
16	2809
17	2809
18	3844
19	4356
20	9025
21	484
22	3600
23	3969
24	2704
25	3364
26	1764
27	3481

TABLE VI (continued)

Student	X_5^2
28	2704
29	3969
30	4489
31	3249
32	2025
33	529
34	3721
35	4096
36	1849
37	2809
38	3844
39	1600
40	4624
41	4489
42	2500
43	2209
44	8100
45	3600
46	2916
47	2401
48	4761
49	3600
50	2209
Total	162513

APPENDIX B

TEST OF SCIENTIFIC BACKGROUND

Each statement in this test is followed by four alternative answers, of which only ONE is correct. Underline the words or word that you regard as being correct.

1. The kindling temperature of a substance is the temperature at which it:

   (a) breaks into small particles,
   (b) catches fire,
   (c) changes from gas to liquid,
   (d) increases number of molecules.

2. Helium is used in balloons instead of hydrogen because it:
   (a) doesn't burn,
   (b) is more abundant,
   (c) burns,
   (d) is active.

3. When air is released from an automobile tire, the surrounding air is:
   (a) heated,
   (b) hardened,
   (c) cooled,
   (d) turned into liquid.

4. A siphon is used for:
   (a) stopping street cars,
   (b) moving liquids,
   (c) putting gas in balloons,
   (d) controlling a dirigible.

5. Air can hold more moisture when it is:
   (a) still,
   (b) colder,
   (c) warmer,
   (d) softer.

6. Dew is water vapor that has:
   (a) come out of plants,
   (b) been warmed,
   (c) condensed from air,
   (d) settled from clouds.

7. The cooling effect observed when a person who is perspiring is exposed to moving air is due to:
   (a) being too hot,
   (b) blood movement,
   (c) evaporation,
   (d) air pressure.

8. In the air near it a fire increases the amount of:
   (a) carbon dioxide,
   (b) oxygen,
   (c) hydrogen,
   (d) nitrogen.

9. The kind of wood used in most model airplanes is:
   (a) poplar,
   (b) balsa,
   (c) mahogany,
   (d) pine.

10. The curve of an airplane wing:
   (a) aids the speed of the motor,
   (b) produces less vibration than other forms,
   (c) gives lift to the plane,
   (d) makes night flying safe.

11. To land an airplane, it should be flown:
   (a) in the direction of travel,
   (b) with the wind,
   (c) across the field,
   (d) against the wind.

12. The boiling point of water on the centigrade thermometer is:
   (a) 100 degrees C.
   (b) 4 degrees C.
   (c) 212 degrees F.
   (d) 273 degrees C.

13. In the process called _____, water is sprayed into the air to help destroy germs present.
   (a) distillation,
   (b) aeration,
   (c) filltration,
   (d) air conditioning.

14. A small calorie is the amount of heat necessary to raise the temperature of a gram of water:
   (a) 54 degrees C.
   (b) 4 degrees C.
   (c) 1 degree C.
   (d) 12 degrees C.

15. A pond freezes in winter:
   (a) from north end to the south,
   (b) from bottom up,
   (c) from the middle in all directions,
   (d) from the top down.

16. Glaciers are composed mainly of:
(a) salt,
(b) rock,
(c) soil,
(d) ice.

17. Of the following, the commonest cause of erosion is desert region is:
(a) plants,
(b) wind,
(c) vapor,
(d) gas.

18. At room temperature oxygen in the atmosphere is a:
(a) solid,
(b) liquid,
(c) vapor,
(d) gas.

19. A much used fireproof material is:
(a) alcohol,
(b) asbestos,
(c) shellac,
(d) asphalt.

20. A form of energy released by oxidation in the human body is:
(a) gravity,
(b) light,
(c) sound,
(d) heat.

21. The solid material remaining after a wood fire is the:
(a) fuel,
(b) ash,
(c) carbon dioxide,
(d) black dirt.

22. In order to radiate heat readily an object should be colored:
(a) white,
(b) red,
(c) black,
(d) silver.

23. One of the greatest dangers from poor electric wiring or poor insulation of wires in homes is :
(a) fuse,
(b) short circuit,
(c) lightning,
(d) humidity.

24. One of three things essential to start a fire and maintain it is a supply of:
(a) light,
(b) oxygen,
(c) nitrogen,
(d) sound.

25. The thermometer scale most commonly used in American homes is:
(a) absolute,
(b) clinical,
(c) Fahrenheit,
(d) Reamur.

26. The presence of molten rocks in the earth is shown by:
(a) cyclones,
(b) volcanoes,
(c) tornadoes,
(d) changing seasons.

27. In the transformation of rocks, linestone is changed into:
(a) graphite,
(b) fossils,
(c) slate,
(d) marble.

28. The principal element in graphite and hard coal is:
(a) bituminous,
(b) carbon,
(c) calcium carbonate,
(d) oxygen.

29. Plant and animal preserved in rocks are called:
(a) fossils,
(b) phospates,
(c) terraces,
(d) flood plains.

30. A study of the composition of matter is called:
(a) physics,
(b) chemistry,
(c) biology,
(d) materalism.

31. Chemists have found that there are about_____different elements:
(a) 34 to 40,
(b) 60,
(c) 20,
(d) 92.

32. The smallest unit of any given element taking part in a chemical change is known as:
(a) a molecule,
(b) an atom,
(c) a calorie,
(d) an element.

33. According to the electron theory an atom of an element consists of;
(a) a compound,
(b) a single unit,
(c) an electric charge,
(d) electrons and protons.

34. Objects at rest have:
(a) inertia,
(b) velocity,
(c) power,
(d) effeciency.

35. Mechanical work done in lifting objects is measured by multplying the quantity of matter raised by:
(a) volume,
(b) distance,
(c) friction,
(d) size.

36. Every plant or animal starts its individual life as:
(a) a bacillus,
(b) an organ,
(c) a single cell,
(d) a nucleus.

37. The actual living substance in all cells is called:
(a) photosynthesis,
(b) proteins,
(c) protoplasm,
(d) cytoplasm.

38. One difference between living machines and non-living machines is that only living machines:
(a) move,
(b) use energy,
(c) repair themselves,
(d) need fuel.

39. The energy of all living things canbe traced to:
(a) bacteria,
(b) sunlight,
(c) soil,
(d) water.

40. Potential energy of waterfall is that due to:
(a) position,
(b) motion,
(c) resistance,
(d) sound.

41. The fact that certain characteristics appear in a species generation after generation is known as:
(a) uniformity,
(b) heridity,
(c) variation,
(d) natural selection.

42. The good or the bad habits that a person acquires in his lifetime:
(a) are inherited by his children,
(b) cross over,
(c) reappear in the grandchildren,
(d) have no influence on the children's inheritance.

43. The most serious effect of alcohol is on the:
(a) Mucous membrane,
(b) stomach and lungs,
(c) brain and nerves,
(d) muscular system.

44. The main reson why animal food should be cooked is:
(a) to make it look more appetizing,
(b) to make it easily digested,
(c) to make it taste better,
(d) to make it tender.

45. Much protein is found in:
(a) eggs,
(b) starch,
(c) celery,
(d) water.

46. In magnetism like poles:
(a) attract,
(b) repel,
(c) are neutral,
(d) conduct.

47. Gasoline trucks are often equiped with a short chain which drags on the ground at the rear of the truck. This is to:
(a) discharge static electricity,
(b) gain energy from contact with the pavement,
(c) create magnetism,
(d) complete a circuit.

48. The unit of electric current is:
(a) ohm,
(b) watt,
(c) ampere,
(d) ion.

49. A dry cell is so called because:
(a) all igredients are absolutely dry,
(b) it has not liquid electrolyte,
(c) outside wrapper is paper,
(d) only works in a dry climate.

50. The device that converts electrical energy into mechanical energy is:
(a) motor,
(b) dynamo,
(c) transformer,
(d) electromagnet.

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