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The Relation Of Statistics To The Design Of Educational And Psychological Investigations

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Cycles of economic conditions had some influence on the number of boys who were farming. As farming conditions improved, more boys went into farming; as economic conditions on the farm became less favorable, the individuals went into other kinds of work.

Many boys, who chose occupations that were different than their fathers, managed to find employment in these other occupations but generally they were in levels of occupational intelligence corresponding to those of their fathers.

Many boys chose occupations in categories higher than those which they were able to reach. A few were working on levels above their choices. The individuals tended to seek their occupational intelligence levels before becoming stabilized. Those in the high intelligence group reached their levels more quickly than those who were in the lower categories.

The individuals in some cases had not reached their levels at the close of the study and might continue to make changes for several years before actually finding satisfactory occupations.

One hundred eighty-seven, or 39.4 per cent of the entire group, were working on the levels of the choices which they made ten years earlier; forty-three, or 9 per cent, were working on levels above their choices, and 161, or 33.9 per cent, were employed on levels below their choices.

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THE RELATION OF STATISTICS TO THE DESIGN OF EDUCATIONAL AND PSYCHOLOGICAL INVESTIGATIONS

ABSTRACT

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The object of statistical methods is to make available all the information furnished by a body of data in its logical bearing upon whatever theories are under consideration. In the present, as well as in the past, especially in the field of educational research, the usual procedure is to collect the data and then decide what statistical treatment will be accorded them in order to elicit their meaning. All too frequently, this policy results in the failure to arrive at unqualified answers to the questions raised. In a field such as ours, where we have drawn largely upon older disciplines for method and treatment the task is an exceedingly difficult one. Very much labor must be consumed in discovering the limitations, both qualitative and quantitative, of such methods when new types of observational data are under consideration or when new

kinds of information are being pursued. All this makes it even more incumbent upon the educational investigator to give most careful consideration not only to the principles to be used in his collection of data but to the statistical treatment to be accorded them, at the time his plans are under formulation. It is believed that only in this way can we build a foundation for designing the nature and extent of observational programs that will elevate the plane of educational research. Too frequently we follow the work of our predecessors or are governed too much by our own mathematical attainments or those of our readers rather than by the methods of design and the statistical methods that will yield the best answers to the questions raised. There is a tendency to emphasize the importance of the procedures with which one is most familiar. Because of this many useful statistical tools lie virtually idle and little progress results from their use or the development of even more appropriate ones. How many of the new books on statistics in education or psychology issuing each year include any of the new developments in statistical theory and practice? The content shows little evidence of change. Examination of the reports of research findings in the literature reveals highly inefficient methods in use, not only in the plan of the investigation but in the methods of analysis used.

The chief purpose of this paper is to direct attention to the importance of treating the design of the investigation and the statistical analysis as but two aspects of the same problem. Only when the relationship between the two aspects is clearly conceived is it possible to collect observational data under conditions which will make them amenable to a valid statistical analysis. Through the application of this principle it is frequently possible to increase the value of the experiment several fold.[1]

The application of the principles of design and of the appropriate statistical methods of analysis is made to a number of educational investigations conducted by the writer. Comparisons are also made between the use of inefficient methods of estimation and the more highly efficient methods very few, if any, of which have been applied by educationalists or psychologists in their investigations.

In the first place, it is shown that a considerable number of problems met with in the field of education and psychology can be expressed mathematically as problems of testing statistical hypotheses. The optimum standard of statistical craftsmanship is attained when, in designing an investigation, we formulate in rigorous, and therefore mathematical terms, the foundations of hypotheses on which the ultimate inferences are to be drawn.

Usually in research, the observed facts are designated as "samples" and the hypotheses pertain to the "populations" from which

[1] R. A. Fisher. *The Design of Experiments.* Oliver and Boyd: Edinburgh. 1935. 252 p.

the samples have been taken. The characters of the samples used in testing the hypotheses are generally functions of the moment coefficients, appropriately used when the variation among the observations is approximately represented by the normal frequency law. But as Neyman and Pearson have pointed out, even though the moments are efficient, considerable choice exists in the particular function of these moments that is most appropriate to the test of a given hypothesis. Blindly adopting the rule,

Standard error of

$$(x\text{-}y) = \sqrt{(\text{standard error of } x)^2 + (\text{standard error of } y)^2}$$

has led to frequent inconsistencies.

In educational experimentation, as in experimentation in other fields, much confusion would often be preventable if the hypothesis to be tested were clearly formulated when the experiment is designed.

The use of "Student's t test" is illustrated in its application to an educational experiment properly designed, and the extension of its use to test more complex situations is described.

One of the most effective statistical methods of securing the whole of the relevant information in a body of data issuing from an experiment properly designed is that introduced by Fisher in 1923, known as the analysis of variance. Two illustrations are given of its application to educational problems, (1) an experiment designed to test the outcomes of three different methods of laboratory instruction in biology and (2) problems in predicting student achievement.

One of the advantages of the method of the analysis of variance, when it is required to determine whether or not several groups of observations are samples from the same homogeneous population, is that it takes into account the sampling distribution of constants of the same kind. The test of the difference between any given pair of corrected means, or of other pairs of constants, involves neglect of the information in the data as to the sampling distribution of this difference.

A statistical technique of major importance is chi-square. Its use as a test of significance for data characteristic of the study of attributes, quite common in educational problems, permits the extraction of all the relevant information which other methods frequently used are incapable of doing. An illustration is given of its use in connection with a study of the relation between types of entrance units and college aptitude, achievement, and other characteristics of students. It is possible to separate the contributions to chi-square from each of the individual degrees of freedom, and so to test distributions by parts.

Another illustration of the relation of statistical analysis to the investigational plan is taken from a curricular study in the field of mechanical engineering. A comparison is made of the quan-

tity of information secured by the method appropriate for the particular form of investigational design and other less efficient methods commonly employed in investigations of this character.

The main points in the paper may be summed up by stating that—

1. The design of an experiment should include consideration of the appropriate statistical tools to be used in eliciting the whole of the information afforded by the data.
2. Tests of significance appropriate to special purposes are illustrated with such important tests to the experimenter as the "t" test and the chi-square test.
3. The arithmetical procedures involved in using the method of analysis of variance and the test of significance appropriate to the findings of such analysis are illustrated.
4. The design of an investigation to secure an unbiased estimate of the relative values of certain prescribed courses in a specialized curriculum is described.

THE PRESENT HIGH SCHOOL COURSE IN CHEMISTRY—A PARADOX

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A STUDY OF THE DIFFICULTY WHICH THE TERMINOLOGY OF SCIENCE INTRODUCES IN GENERAL EDUCATION

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