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The Application of Elementary Statistics In Analysis of Data by Selected Secondary School Students

Charles Martin Bridges Jr.
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Charles Martin Bridges Jr. entitled "The Application of Elementary Statistics In Analysis of Data by Selected Secondary School Students." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Education, with a major in Education.

W.W. Wyatt, Major Professor

We have read this thesis and recommend its acceptance:

Earl M. Ramer, A. Montgomery Johnston, Galen N. Drewry, Lewis C. Copeland, George W. Wiegers

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

June 7, 1959

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W. W. Wyatt
Major Professor

We have read this thesis and recommend its acceptance:

[signatures]

Accepted for the Council:

Dale Hartling
Dean of the Graduate School

THE APPLICATION OF ELEMENTARY STATISTICS IN ANALYSIS OF DATA BY SELECTED SECONDARY SCHOOL STUDENTS

A DISSERTATION

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Doctor of Education

by

Charles Martin Bridges, Jr.

June 1959

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CHAPTER I

INTRODUCTION

During the past decade a revival of interest in the curriculum of the secondary school has been exhibited by mathematicians and members of various mathematical associations. As a result of this interest, the mathematics program appears to be undergoing a process of redesigning. With increasing interaction of the disciplines, including mathematics and science, the traditional mathematics program is being studied in an attempt to bring it more into line with current demands. With the advent of computers, emphasis on certain methods for the solution of equations is of less importance today.

One of the needed areas of mathematics is that of developing the facility to analyze data collected in an experimental situation and to draw conclusions about the populations from which samples were drawn. This is the province of statistical inference and the associated aspects of probability.

Statistical procedures are applied in many instances in education, in business, in the social sciences, and in the natural sciences. Mathematical analysis of data rather than a rational analysis of data is becoming more evident. A clothing manufacturer is interested in the distribution of sizes needed for potential customer population. This manufacturer also wishes to present merchandise of acceptable quality at a minimum cost. Control of the mass production process is necessary. These are some of the problems of the quality control statistician.

The citizen buys insurance as a protection against the probability that his property will be damaged or destroyed. The insuror uses the laws of probability to determine the amount that this protection will cost the insured.

The social scientist uses principles of statistical inference in a study of social structure, economics, and the interaction of common factors. The psychologist in a study of the individual, his aptitudes, intelligence, and personality makes use of statistical procedures to interpret data.

While it ~~is~~ should not be the intention of the secondary school to produce "finished" statisticians, an introductory course may serve as an indicator of the possibilities of this field of study.

Statement of the Problem

The purpose of this study was to determine the ability of apt secondary school students to apply principles of elementary probability and statistical inference in the analysis of data following a semester of instruction in statistics and elementary probability.

Importance of the Study

The importance of this study is:

1. In many instances curriculum revision has been attempted through uncontrolled judgment or opinion, leading to an accretion of courses in the typical secondary school program. Instead, any revision

of the program of study should be attempted in light of experimental data where practical.

2. Before interjecting new subject matter into the curriculum, some knowledge of the limits of acheivement for apt secondary school students is necessary. Knowledge of these limits serves as a more reasonable basis for selection of level of content.

3. The use of statistical procedures, as a tool comparable to other mathematical processes, may open areas for investigation that would otherwise go undetected or in certain instances would be beyond solution.

Assumptions

Assumptions basic to this study are:

1. The application of the principles of statistical inference is important in the process of utilizing the scientific method in the solution of problems.

2. Statistics is appropriate in that it serves as an informative type of course, and an introductory experience in an area which may conceivably become a field of further specialization.

Limitations of Study

This study is limited to data obtained from the sample group of those students enrolled in a class in advanced mathematics at Bearden High School, Knox County, Tennessee. This group was composed of four juniors and fifteen seniors.

The control group was composed of students enrolled in a Plane Geometry class at Bearden High School, Knox County, Tennessee.

The study is further limited to a determination of the ability of apt secondary school students to apply the principles of statistical inference and probability in the analysis of data.

Related Studies

As early as 1920, reference may be found relating to the teaching of statistics in the secondary school.[1] One of the studies of this early period in mathematics education was that of the Mathematical Association of America in 1923.[2] In these studies, the suggested organization of the statistical instruction was restricted to that of descriptive statistics with the additional concepts of central tendency and variability.

One of the major studies of more recent years pertaining to mathematics education was that of the Progressive Education Association.[3] In this report the statement was made that:

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[1] Truman L. Kelley, "Elementary Statistics in High School as a Socializing Agency," School and Society, 11:228-30, February, 1920.

[2] The Mathematics Association of America, The Reorganization of Mathematics in Secondary Education. Part I. A Report of the National Committee on Mathematical Requirements (Cambridge, Massachusetts: The Riverside Press, 1927).

[3] Commission of the Secondary School Curriculum of the Progressive Education Association, Mathematics in General Education: Report of the Committee on the Function of Mathematics in General Education (New York: D. Appleton-Century Company, Inc., 1940).

> . . . the emphasis has been largely upon . . . computational aspects. The interpretation of statistics and discussion of the relative advantages and disadvantages of various measures has been seriously neglected.[4]

The writers of this report at first emphasized the nature of statistical procedure from purely a descriptive viewpoint, but later introduced the idea that certain inferential procedures are imperative in the process of analyzing data and solving problems.

In more recent years, the Mathematics Commission of the College Entrance Examination Board and the National Association of Teachers of Mathematics have undertaken the task of developing materials for suggested additions to the secondary school mathematics curriculum. The National Council presented their collective thoughts in the Twenty-Third Yearbook of the National Council of Teachers of Mathematics. This publication, among other topics, presents a discussion of the various concepts of probability which might be included in a secondary mathematics program.[5] The Mathematics Commission has published a book containing what is described as an experimental course in elementary probability and statistical inference.[6]

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[4] Ibid, pp. 121-22.

[5] Herbert Robbins, "Chapter XI, The Theory of Probability," Twenty-Third Yearbook, Insights into Modern Mathematics (Washington, D. C.: The National Council of Teachers of Mathematics, 1957), pp. 336-371.

[6] Commission on Mathematics, College Entrance Examination Board, Introductory Probability and Statistical Inference for Secondary Schools, An Experimental Course (Preliminary edition; New York: College Entrance Examination Board, 1957).

Beberman[7] and O'Toole[8] presented doctoral studies in 1952 relating to statistics in the secondary school program. Beberman's study is centered around justifying the inclusion of statistics in the secondary school program. The general concensus of the thesis with respect to this is that education has two responsibilities resulting from demands of society. The first of these demands relates to the need for trained statisticians for industry. It is recognized that the responsibility for producing these trained people rests not with the secondary school as such but rather the secondary school is assigned the responsibility of creating an appreciation and an awareness of the role of statistics. By doing this the schools may indirectly serve the purpose of awakening the interest of capable students and calling their attention to the vocational possibilities of statistics. The second function delegated to the secondary school is that of developing a certain proficiency in statistics. The statement is made that before society can make full use of statistics, it is necessary that statistically literate people be developed.

Beberman states that the only reason for the inclusion of any

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[7] Max Beberman, "The Teaching of Statistics in Secondary School Mathematics" (Unpublished Ed.D. Project Report, Advanced School of Education, Teachers College, Columbia University, February, 1953).

[8] Alphonsus Lawrence O'Toole, "Statistics in the Secondary-School Curriculum" (Unpublished Ed.D. Thesis, The Graduate School of Education, Harvard University, 1952).

subject matter into the curriculum is that the added material will better enable the school to fulfill its function in a democratic society. He apparently bases his subject matter content upon the findings of his survey of secondary school mathematics texts and other materials appearing to be significant to him.

Beberman further identifies in his work the areas of statistics to which he feels the secondary school should give attention. The areas are

1. the collection of data
2. the description of data
3. the interpretation of data

O'Toole's major contribution in his study is the detailed outline for a proposed course in statistics for the secondary school mathematics program. The recommendation was made that this material be placed in the eleventh and twelfth grades and be substituted for the conventional algebra. O'Toole does not make a statement as to whether or not this material is to be presented to all students taking second year algebra or to a special group.

The body of subject matter formulated by O'Toole and suggested for the statistics program included:

1. The Components of a Statistical Investigation
2. Measures of Central Tendency and Variability
3. Sampling and Elementary Experimental Design
4. Elementary Probability
5. Discrete and Continuous Distributions

6. Tests of Hypotheses

   a. Student-t distribution
   b. Chi-square distribution
   c. Analysis of Variance
   d. Correlation and Regression

7. The Preparation of Statistical Reports

O'Toole justifies his course and its content on the basis that it will aid the student in being better able to solve social problems.

Of the units which have been taught and reported, Olander[9] gives a complete report of the content of his course. The major weakness of this report is that relating to the evaluation procedure. Four questions were asked. "Why should statistics be taught?" "What should be included in a course in statistics for secondary school students?" "How should a course in statistics for secondary school students be conducted?" "Where should statistics be placed in the curriculum?" Olander answers these questions by describing his own work. In so doing some important observations are made.

In answering the first of these questions -- "Why should statistics be taught?" -- the following points are made. The average citizen is asked to digest much information today involving the necessity for statistical interpretation. Five objectives are given for the course in statistics:

1. Understanding the role of mathematics and probability in statistical reasoning.

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[9] Clarence E. Olander, "Lets Teach Statistics," The Mathematics Teacher, 51:253-60, April, 1958.

2. Understanding the types of problems in society that can be solved statistically.

3. Understanding the basic statistical techniques, concepts, and methods.

4. Ability to define a problem, design, and carry out the proper statistical analysis necessary to draw valid conclusions.

5. Appreciation of the limitations of statistical inference and an understanding of the generalizing ability of experimental evidence.

In answer to the question of placement of statistics in the curriculum, Olander indicates that statistics may be developed as an academic subject throughout the entire school program both on the elementary and secondary levels. If it is not to be taught in this manner then it is recommended that the most logical place for its inclusion in the program would be within the area of mathematics. It was proposed that this inclusion could be accomplished in one of two ways:

1. Be made into a grades 7-12 sequence, or

2. Be a one semester course in mathematical statistics replacing a semester of conventional mathematics.

In discussing what should be included in a course in statistics for secondary school students, the comment is made that throughout a course of this nature, it should be remembered that mathematics is assuming the role of an applied science. In most instances a distinction is made between descriptive and inferential statistics. It was proposed that the descriptive techniques be used as a means for carrying out statistical inference. The following activities were suggested as being worthy of accomplishment:

1. Develop a feeling for the nature of statistics
    a. Discuss various aspects of statistical reasoning as applied to an introductory problem to include the identification of a problem, obtaining the sample, stating the hypothesis, and procedures used in testing the hypothesis.
    b. Introduction to sampling techniques.
2. Study probability

    Include the study of permutations, combinations, binomial theorem, probability theorems, empirical probability, and probability distributions.
3. Develop an understanding of statistical reasoning to include
    a. the logical role of statistics.
    b. the limitations of statistics.
    c. the comparison of kinds of reasoning.

In considering how a course in statistics should be conducted, emphasis is placed on the fact that the objective of such a course in statistics is not to train research statisticians but to give students some impressions of statistical reasoning and kinds of problems that can be solved through statistical reasoning with the associated limitations.

> The approach must allow students to develop an understanding of the statistical methods under consideration. The fact that a student can perform mathematical techniques, indicates very little as to understanding. Furthermore, a knowledge of the steps involved in testing a hypothesis does not guarantee that the student has a fundamental knowledge concerning the acts of inference. Often times the blind mechanical use of various

> formulas seems to add to the general confusion. The interpretation of statistical reasoning can be understood most easily if the general problem is first studied from its logical, rather than its mathematical aspects.[10]

Briefly Olander approaches the question of organization of the course by saying, the class instruction should start with some idea of the meaning of statistical reasoning. The student should understand that statistical reasoning begins with a clear concise statement of the problem and ends with probability statements concerning the hypothesis formulated from the problem.

It was then suggested that a study of probability follow the introductory sessions on statistical reasoning. Within this can come an understanding of discrete and continuous variables. The binomial theorem and distribution should then be explored and the normal distribution may be introduced showing its relationship to the binomial.

With the developed understanding of these sampling distributions, the student would then have a good background for testing statistical hypotheses and the functional application of the principles of statistical inference.

It should be noted that in these reports, there is no mention at any place of an attempt to evaluate objectively the effectiveness of the proposed course.

Hypotheses

The test hypotheses in this investigation are:

1. There is no significant difference between the pre-test

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[10] Olander, p. 256.

scores and the post-test scores for the experimental group.

2. There is no significant difference between the pre-test scores and the post-test scores for the control group.

3. There is no significant difference in the ability of apt secondary school students who have completed a semester in elementary probability and statistical inference and that of apt secondary school students who have not received instruction in elementary probability and statistical inference in applying the concepts and principles related to this course, as measured by post-test scores.

Methods of Procedure and Sources of Data

In pursuing the problem basic to this study certain sub-problems were encountered which served as guides in determining the methods of procedure and the methods of collecting and evaluating data.

1. A semester course of study in elementary probability and statistical inference applicable to secondary school students was developed.

In the process of formulating the body of subject matter to be included in the course of study, members of the staff of the Statistics Department of the College of Business Administration were consulted and their recommendations were collected. A second source of guidance for the selection of this material was the literature relating to elementary statistics. Numerous articles have been published suggesting various topics considered by the respective authors to be important. A third source of information was several of the standard texts in elementary statistics. The various general and specific topics collected from these sources were tabulated and from this basic outline the organization of the course was determined. Concurrent with the determination of the body of subject matter to be included, was the selection of the instructional procedure. In teaching these classes, the lecture method of presentation was relied upon primarily. Where possible, exercises such as sampling from particular populations, drawing graphs from these data, and determining the relationship between variances for distributions of sample means of various size samples were utilized. In addition, considerable emphasis was given to the solving of exercises.

2. An adequate testing instrument which would measure the ability of selected secondary school students to apply the principles of elementary probability and statistical inference in the analysis of data was developed.

This instrument was developed in the light of the objectives of the course. The body of subject matter was viewed in terms of these objectives and test items were developed which would evaluate the ability of the students to utilize this material. These test items were then submitted to the jury used in the formulation of the subject matter and also to the Head of the Tennessee State Testing Program. Two forms of the evaluative instrument were developed. Form A (Appendix A) was used at the beginning of the period of instruction and Form B (Appendix B) was administered at the end of the semester of instruction.

3. A group of apt secondary school students was selected and permission was secured from the responsible persons for carrying out the study.

The group used in this study was enrolled in an experimental class in Bearden High School, Knox County, Tennessee. This group was a pilot study group for the county system where various topics in advanced mathematics beyond the usual secondary school mathematics content were being examined. Four of the members of the class had completed two years of secondary school mathematics while the remainder had completed three years of work. All of these students were taking a second course in mathematics in addition to the experimental course.

In securing permission for the course involved in this study, it was necessary to receive the permission of the resident mathematics teacher, principal, superintendent, supervisor of instruction for the county, and the State Board of Education. A proposed course of study was submitted to each of these elements in turn.

This permission was sought under the ruling given in the State Department of Education's bulletin which is as follows:

> This requirement does not prohibit local school systems from offering instruction in additional areas, or in additional courses, provided that courses of study are submitted to the State Board of Education for approval.[11]

Furthermore, the proposal was in line with one of the Tennessee State Department of Education's "Basic Beliefs Underlying a Program of

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[11]Tennessee State Board of Education, 1957-59 Rules, Regulations, and Minimum Standards of the Tennessee State Board of Education (Nashville, Tennessee: State of Tennessee, 1957), p. 45.

Public Instruction," viz., "Belief in the Methods of Experimentation and Research.[12]

Organization of the Study

Chapter I contains the statement of the problem, the importance of the study, the basic assumptions, the limitations of the study, the review of the related literature, the hypotheses, the methods of procedure and sources of data, and the organization of the study. The statement of the objectives of the course taught to the students, a description of the course in statistics and probability taught to the students, and a statement of the methods of evaluating the course are stated in Chapter II. Chapter III is a presentation of the data with the statistical analysis of the test validity, test reliability, and the tests of the hypotheses for the study. Chapter IV contains a summary of the study and the conclusions reached as a result of the investigation.

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[12]Letter from R. R. Vance, Director, Instructional Administration, Department of Education, State of Tennessee, to C. M. Bridges, Jr., dated July 16, 1958.

CHAPTER II

DESCRIPTION OF THE COURSE

In developing any course of study, it is important that the objectives of the course be determined and used thereafter as a basis for the selection of subject matter, methodology, and evaluative techniques.

In developing the objectives for this course, it was necessary to keep in mind that the primary concern of the course was not to develop research statisticians, but rather the development of a basic understanding of statistical reasoning and certain computational skills by the students. As was stated in Chapter I, there are no reports in the literature describing a controlled study to determine the ability of students on the secondary school level to understand and apply the principles of statistical inference and probability in the solution of problems involving the analysis of data. In suggesting the possible addition of statistical inference and probability to the mathematics curriculum of the secondary school, the major objective for some seems to be the development of the ability to analyze data. With the increasing importance of the scientific method in the program of the students, some attention to the place of statistics may become necessary. The major purpose in the addition of a course of this type would be to enable the student to better analyze problems. With these ideas in mind the following objectives were formulated for the course.

1. The student may develop an understanding of the types of problems that can be approached through the use of statistical

procedures.

2. The student may develop an understanding of some basic statistical techniques, concepts and methods.

3. The student may develop the ability to define a problem, design a simple experiment, and utilize the principles of elementary probability and statistical methods in the analysis of data.

4. The student may develop an appreciation of the limitations of statistical inference and an understanding of the limits within which generalizations may be made from experimental data.

The understanding sought in the first objective would be developed throughout the period of the course. As each of the various statistical techniques was developed, examples of the types of problems where the specific technique was applicable was given.

The second objective was achieved through the study of a body of subject matter in elementary probability and statistical inference. Table I, Time Schedule for the Presentation of the Areas of Subject Matter, presents the major subject matter areas and the amount of time spent on each.

Components of a Statistical Investigation

The first seven hours of the course were spent discussing the various components of a statistical investigation. Covered in this discussion were such topics as continuous, discrete, qualitative, and quantitative variables, population, sample, types of descriptive techniques

TABLE I

TIME SCHEDULE FOR THE PRESENTATION
OF THE AREAS OF SUBJECT MATTER

	Area		Time in Hours
I.	The Components of a Statistical Investigation		7
II.	Measures of Central Tendency and Variability		7
III.	Elementary Probability		10
IV.	Discrete Distribution Functions		12
V.	The Normal Distribution		7
VI.	Tests of Hypotheses		30
VII.	Developing the Statistical Report		5
		Total	80

including histograms, frequency polygons, cumulative frequency polygons, and ogives. Distinction was made between a continuous distribution and a discrete distribution.

Measures of Central Tendency and Variability

The second major area was the measures of central tendency and variability. In discussing the measures of central tendency -- mean, median, mode -- these factors were presented as one means of locating a distribution within the continuum of the number system. The measures of variability -- variance and standard deviation -- were approached through the use of the least squares technique. The discussion of this material was limited primarily by the mathematical background of the students in the class, notably the lack of the calculus. These were presented as further ways of describing a distribution of variables.

Exercise sheets were given to each of the students. Following are some examples of the types of exercises the students were asked to do. The students were asked to compute the mean, range, median (where possible), mode (where possible), variance, and standard deviation.

1. 46, 51, 52, 48, 50.
2. 4, 6, 8, 3, 5, 2, 7, 9, 11, 3, 4, 3.
3. 16.1, 15.9, 15.8, 16.2, 16.3, 15.6, 15.9, 15.8, 15.9, 15.6.
4. 161, 159, 158, 162, 163, 156, 159, 158, 159, 156.
5. 1510, 1550, 1600, 1520, 1530, 1540.

Where appropriate, the students were instructed to code the data for ease in computation.

Elementary Probability

Before proceeding to any of the types of frequency distributions, it was thought necessary to present some of the fundamentals of elementary probability. Within this area the following concepts were developed:

1. The probability of the occurrence of a single event
2. The idea of sample space
3. The addition rule
4. The multiplication rule
5. Combinations
6. Permutations

These ideas were given an empirical basis up to the extent that dice, coins, playing cards, and other such items were used as sources of data. Along with the discussion, the students were asked to work certain exercises such as the following:

1. What is the probability that two cards drawn at random, with replacement, from a standard deck will not both be of the same suit?

2. One bag contains two white beads, three yellow beads, four red beads, and five blue beads. Another bag contains five white beads, four yellow beads, three red beads, and two blue beads. One bead is drawn at random from each bag. What is the probability that both will be of the same color?

3. An unbiased coin is tossed 200 times. What is the standard deviation for the distribution of values?

4. A group of people started out on a trip by boat. Three of the group did not reach the destination. The remaining members of the group returned by airplane. Four of the group stopped at destinations along the return route. What is the probability that a given person in the group did not complete the trip?

5. A certain game of chance has 200,000 tickets numbered serially and priced at five dollars each. Two tickets chosen at random will pay $15,000 each to their purchaser. What is a purchaser's expectation of value from a single ticket?

Discrete Distribution Functions

Following this discussion of some of the simpler forms of probability, the discrete distribution functions -- binomial, Poisson, hypergeometric -- were discussed. The conditions under which each of these functions was applicable were pointed out. Also it was pointed out to the students that the binomial distribution is the basic distribution and that the other two discrete distributions were approximations of this function. Representative examples of the types of exercises worked by the students during this period were:

Binomial Distribution

1. A distributor of seeds determined over a period of years of testing that 3 per cent of his seeds will not germinate. He sells the seeds in packages of 150 seeds and guarantees 95 per cent germination. What is the probability that a given package will not meet the guarantee?

2. If a true coin is tossed ten times, what is the probability of getting at most eight heads?

Poisson Distribution

1. Suppose that the number of telephone calls handled by a particular telephone operator during a given five minute period follows a Poisson distribution, with a mean of four. What is the probability that the operator will handle no calls during the same period on a given day?

2. An insurance company finds that the probability of a certain aged person dying during a given year is 0.0002 from a specific disease. What is the probability that two out of

100,000 insured risks of this age will die of the disease during the year?

Hypergeometric Distribution

1. A grocer knows that in a particular lot of 500 apples there are twenty-five bad ones. What is the probability that a sample of twenty apples will contain three of the bad apples?

2. If any bad apples are found in the sampling process, the lot will be rejected. What is the chance of this event occurring?

The Normal Distribution

The normal population and normal distribution were presented next. The normal distributions of separate values and of sample means were treated. The students were asked to carry out certain exercises related to the determining of the probability of the occurrence of a range of values as well as a range of sample means in a given normal distribution. Examples of these exercises were:

1. Given a normal distribution with a mean of sixteen and a standard deviation of two, what is the chance that a value of X picked at random will lie within three units of the mean? Will it be at least four units different from the mean?

2. If one hundred objects are selected at random from a population having $\mu = 25$ and $\sigma = 4$, how many could be expected to have values of at most 27? at least 23? exactly 23?

3. A manufacturer of a type of metallic strips guarantees that no more than one in 500 will be narrower than 0.25 inches. The standard deviation for the manufacturing process is 0.004 inches. What is the probability that a sample of twenty-five strips will have an average width of at least 0.252 inches?

4. Samples of size thirty-six are drawn from a universe with $\mu = 100$ and $\sigma^2 = 196$. What proportion of the sample means may be expected to have values less than 95.43?

5. A true-false test has fifty items. What is the approximate probability of a student answering thirty of the questions correctly by flipping a coin?

6. A bin of electrical switches contains 2 per cent defectives. What is the chance that a sample of thirty-six will contain six defective switches? Work this two ways.

In presenting the distribution of sample means, it was appropriate to present the <u>central limit theorem</u> and the standard error of estimate. Empirically this was done by taking a population of poker chips numbered to follow a normal distribution and comparing the distribution of the single values with distributions of sample means for samples of varying sizes. The relationship of the variances of the single value and sample mean distributions tended to implement the discussion of the standard error of estimate. Along with the distribution of sample means, the distribution of sample proportions was also introduced.

Tests of Hypotheses

Following this preliminary work, the students were then given their initial introduction to the concept of statistical inference. The thought of making a statement concerning the probability of the occurrence of a sample mean within a given hypothesized population was developed. In this case both of the population parameters (mean and standard deviation) were known. Also included within the framework of this section were the concepts of point estimates of the true population mean, confidence interval estimates of the true population mean, and the sample size necessary for a prescribed degree of accuracy in estimating the mean. The students were given a format for setting up the solution of problems involving the testing of hypotheses:

1. Statement of the problem or question of concern

2. Statement of the statistical null hypothesis

3. Statement of the level of significance and the placement of this probability

4. Statement of the critical regions

5. Computation of the sample statistic

6. Action with respect to the test hypothesis (i.e., accept or reject the hypothesis on the basis of the data). When the hypothesis was rejected, the student was asked to calculate the appropriate confidence interval estimate of the true mean for the population from which the sample was drawn.

An example of the types of the types of exercises used in this section is:

A certain munitions manufacturer guarantees that a particular type of anti-tank mine fuse will not detonate more than five times in a thousand with a pressure of less than two hundred pounds. The standard deviation for the manufacturing process is five pounds. What is the mean of the population of fuses? Upon receipt of a shipment of these fuses, a sample of twenty-five yielded a mean firing pressure of 209.5 pounds.

a. At the 1 per cent level of significance, would you accept the shipment?

b. What is the probability of obtaining a sample of twenty-five fuses with an average firing pressure of 210.5 pounds or less from a lot of fuses in which the true mean is really 212 pounds?

c. Since you have rejected the hypothesis, what is your best single point estimate of the true mean for the population from which the sample was drawn?

d. Under the test you have set up, if the true mean of the lot is 210.5 pounds:

   (1) How often will you reject the hypothesis and conclude that the fuses are below standard?

   (2) How often will you accept the hypothesis and conclude that the fuses are acceptable?

e. What would you conclude concerning the hypothesis if you were to take a sample of only sixteen fuses?

f. What size sample would be necessary if you wanted the sample mean to be no more than two pounds different from the true mean with 95 per cent confidence?

g. If you were to take into consideration a power of 90 per cent and the desire to be able to distinguish between population means at least two pounds different, how would this affect your sample size?

As can be seen by parts d, f, and g of this sample exercise, the Type II or β error and the power of the test $(1 - \beta)$ were also discussed.

The testing of hypotheses for single population proportions or percentages was also discussed at this time. It was pointed out that in many cases industrial testing is done in terms of defective parts or merchandise and this technique was used primarily in these instances. Sample exercises used for this were:

1. A certain factory had a daily absentee rate of 2 per cent on the average. On a particular day a department in this factory had nine workers out of 100 absent. Would you say that something in addition to chance was influencing the departmental absentee rate? What would be the 99 per cent confidence interval estimate of the true population proportion for the department in question?

2. A certain manufacturer receives a response from about 2 per cent of the advertisement brochures sent out on the average. A new type of advertising campaign is tried out on 2500 randomly chosen consumers, and 119 responses are received. Is the new type of advertising program more effective than the old type?

The students were then presented with the more prevalent situation where the population standard deviation parameter is not known. The idea of using an estimator, the sample standard deviation, in the test of the hypothesis led to a discussion of Student's-t distribution. The associated confidence interval estimate was also presented.

Example exercises used with this section were:

1. A test was given to a sample of 19 students and found to have a sample mean of 72.74 with a standard deviation of 11.13. At the 0.01 level of significance, does this indicate that the group is above average if the population mean is 66.07? If the hypothesis is rejected, compute the 99 per cent confidence interval estimate of the true mean.

2. A chemist made four determinations of the melting point of Ruthenium: 2550.95, 2551.00, 2550.50, 2550.75 degrees Centigrade. Are these findings in accord with the value reported in the Handbook for Chemistry and Physics? Calculate the 95 per cent confidence limits for the true mean.

After completion of the discussion pertaining to the testing of hypotheses for single population parameters, the next step was the presentation of the methods for testing hypotheses concerning the equality of two population parameters. The tests for equality of means for the normal distribution with the population standard deviations given (z-test) and where the population standard deviations were not given (t-test) were the same with slight modification of one instance. Where a common variance was assumed in the t-test, the pooled variance concept was presented. The general case for this was presented in that in the later subject of the analysis of variance, the same type of statistic would be used. The testing of hypotheses for paired data was also presented at this time.

Sample exercises for the section on Tests of Hypotheses Concerning the Means of Two Populations were:

1. If a sample of four items from a normal population with a variance of four has the values of -3.3, 3.0, 1.0, and -3.8, and a sample of four items taken from a normal population with a variance of five has the values 5.0, 0.0, 2.2, 0.6, would you be justified in saying that the means of the two populations are the same?

2. Eight stores are randomly selected in a particular town and found to have the following percentages of total sales delegated to "hard-line" merchandise: 8.2, 7.7, 9.9, 6.4, 10.3, 7.1, 6.9, 9.8. A sample of nine randomly selected stores in another town of approximately equal size showed the following percentages: 11.0, 9.1, 7.7, 8.3, 7.9, 10.4, 9.8, 11.2, 7.9. Assuming a common variance, is this evidence that the two towns differ significantly in percentages of total sales belonging to "hard-line" merchandise? Estimate with 99 per cent confidence the true difference between the mean percentages.

3. Each of twelve pieces of cloth were divided into two equal parts. One-half was treated in a particular manner before dyeing and the other half was untreated. The following are percentages of shrinkage for the pieces of material:

Treated	1	1	2	3	1.5	3	1	2	1.5	1	2	3
Untreated	2	2	1	3	2	4	2	3	3	4	1	4

Is this evidence that the treatment affected the shrinkage rate?

Since the Chi-square distribution was used in the testing of hypotheses concerning the equivalence of two or more population proportions as well as in other tests, discussion of some of the characteristics and functions of this distribution was appropriate. Associated with this preliminary discussion certain exercises in the empirical construction of the distribution were carried out. A box of poker chips, each numbered in accordance with a normalized distribution, was used in obtaining samples of size n. Samples of four chips were drawn until one hundred such samples had been accumulated. One hundred samples of size two were also drawn. The sample variance of each of the samples was computed and then displayed as histograms for sample variances of size two and size four.

In addition to these, the Chi-square distribution was used in tests for independence of data, tests for goodness-of-fit, and tests of hypotheses concerning a single variance and the estimation of the population variance. The latter test was shown to be based upon the distribution of $\chi^2/d.f.$.

Example exercises for this section were:

1. A manufacturer of a certain type of casting inspects these castings for faults by means of X-ray. Of 4,000 castings coming from production line A, 120 were rejected. Of 3500 castings coming from production line B, 130 were rejected. Is the workmanship of production line A the same as for production line B?

2. Records of the numbers of failures in a particular subject have been kept at two certain colleges. Out of 2,000 freshmen taking this course in a particular year, 10 per cent failed in college A and 12 per cent of 2500 students failed in college B. Can it be said that the percentage of failures at college B is higher than at college A for this particular course?

3. In eighty-one offspring of a certain cross between cattle, eighteen were red, forty-two were roan, and twenty-one were white. According to the genetic model of this cross, these numbers are expected to be in the ratio of 1:2:1. Are the data consistent with the model at the 10 per cent level?

4. In an opinion poll concerning a forth-coming referendum, the individuals interviewed stated their views as follows:

	For	Against	No Opinion
Men	950	2254	486
Women	882	2166	724

   Is this evidence that attitudes reflected in these answers are independent of sex?

5. A chemist made four determinations of the melting point of Ruthenium: 2550.95, 2551.00, 2550.50, 2550.75 degrees Centigrade. After evaluating the various errors contained in his procedure, he decided that the variability in the technique should yield a maximum variance of 0.0195. Are the data consistent with the supposition at the 5 per cent level?

6. Given the following sample variances assumed drawn from a normal universe with a common variance.

$$s_1^2 = 35, \; n_1 = 8$$

$$s_2^2 = 46, \; n_2 = 8$$

$$s_3^2 = 26, \; n_3 = 13$$

Find the 99 per cent confidence limits for the universe variance.

To test hypotheses concerning the equality of two population variances and equality of more than two population means, it was necessary to develop an understanding of the F-distribution. This was done by the use of the ratio of the χ^2/d.f. for one sample variance to the χ^2/d.f. for the second sample variance. It was further explained that in cases where tests concerning the equality of two population means were to be carried out and the assumption of the common variance could not be made, it would be mandatory for the F-test for equality of variances be utilized.

Following are two examples of the types of problems worked in connection with this topic:

1. A sample of thirty-five items drawn from population I had a variance of thirty, and a sample of sixty-four items drawn from population II had a variance of twenty-five. Test the following hypotheses:

   (a) $\sigma_1^2 = \sigma_2^2$

   (b) $\sigma_1^2 \leq \sigma_2^2$

2. In the use of certain instruments, the measure of the adequacy of the instrument is the variability of the errors made. To compare two types of instruments, I and II, the following data were collected:

   I: $n_1 = 35$, $s_1^2 = 40$; II: $n_2 = 46$, $s_2^2 = 30$

   (a) Test the hypothesis that the variances of the errors of I and II are the same.

   (b) Find the 95 per cent confidence interval estimate for the ratio of the population variances.

The analysis of variance technique for testing hypotheses concerning the equality of more than two population means was introduced. It was pointed out to the students that certain basic assumptions were necessary before this particular technique was applicable (i.e., common variance between the populations under consideration, normality of distributions, and randomness of samples). Both the one and two classification procedures were examined.

Examples of the types of exercises used with this topic were:

1. Following are the grade point averages of five sophomores, four juniors, and six seniors. Is there evidence that the class mean averages differ significantly?

Sophomore	Junior	Senior
2.5	2.7	3.1
2.3	2.5	3.3
2.7	2.8	2.4
3.2	2.9	2.5
2.6		2.7
		2.5

2. Three varieties of tomatoes, A, B, and C, were treated with six types of fertilizers (1-6). Following are the average weights per tomato per variety and type of fertilizer:

	1	2	3	4	5	6
A	1.0	1.3	0.9	1.1	1.6	1.3
B	1.5	1.6	1.1	1.3	1.4	1.7
C	1.3	1.8	1.2	1.2	1.7	1.2

Is this evidence that there is a significant difference between the varieties of tomatoes or the effects of the types of fertilizers?

In approaching the last section studied during the period of the course, it was felt that a review of the mathematics involved in determining the equation of a straight line from observed data would be appropriate. With this background, discussion proceeded to the computation of the regression line for sample data. At this point the <u>method of least squares</u> was considered again. This latter concept was used in developing the method of the <u>product-moment coefficient of correlation</u>. Tests for hypotheses concerning (1) the slope of the regression line as an indicator of dependency of data, (2) linearity of data, (3) <u>rho</u> being equal to zero, (4) <u>rho</u> being some value other than zero (using the Fisher z-transformation), and (5) confidence interval estimates for $\mu_{y.x}$, B, A, X, Y_c, $\sigma^2_{y.x}$, Y, and <u>rho</u> were included.

Where appropriate the students were asked to do the following in the solution of exercises related to this area: (1) prepare a graph of each exercise, (2) calculate the regression line for the data and plot this on the graph, (3) test the hypothesis that B is zero, (4) test for linearity of data, (5) calculate r, (6) test the hypothesis that <u>rho</u> is zero. Examples of these type exercises were:

1. Grades of ten students on an intelligence examination (X) and their grades on a statistics examination (Y) were:

X	127	126	120	108	113	150	138	137	141	135
Y	87	73	67	87	70	67	60	57	80	87

2. A sample of sixteen yielded a r of 0.70. Could the <u>rho</u> for the population sampled be 0.78? Calculate the 99 per cent confidence interval estimate for <u>rho</u>.

3. For a sample of twenty-four observations r was found to be 0.87. Does <u>rho</u> differ significantly from zero at the 1 per cent level? For the same sample, b was found to be 0.704, $s_{y.x}$ was 0.126, and the sum of the X^2 was 7.03. Does B differ significantly from zero?

4. Is a correlation coefficient of 0.30 based on a sample of forty-two items significant at the 5 per cent level? How large must r be to be significant at the 1 per cent level?

In Chapter III, lists may be found giving the titles of the individual problems the students attacked and the methods used by them in their statistical analyses.

The course was evaluated in two ways, one of which was to determine the grade the student earned during the course, and the other for the purposes of this study. In the former case, several ten minute quizzes were given in addition to four one-hour examinations, a final examination, homework, and the individual research project. For the purposes of this study, the course evaluation was accomplished through the administration of the test instrument, A Test of General Proficiency in Elementary Statistical Inference, and the research project. The discussion of the data concerning this phase is presented in Chapter III.

CHAPTER III

PRESENTATION OF DATA AND FINDINGS

In determining the validity and reliability of the test instrument, the techniques described by Gulliksen[1] were used. Table II, Item Scores, Criterion Scores, and Total Scores For the Experimental Group on A Test of General Proficiency in Elementary Statistical Inference, Form B, Parts I and II, presents a breakdown by items and by student within the first two parts of the test. Where the student marked the answer correctly the figure one (1) was placed in the appropriate block and where the student did not mark the question correctly the space is left blank. The objectives stated in Chapter II were used as the criteria for the evaluation of the results of the test. Items 1 through 15, 17, 24, and 27 were used to evaluate the first objective or criterion. Items 16, 18, 19, 21, 22, 25, 29, and 33 were used to evaluate the second objective or criterion. Items 20, 23, 26, 28, 30, 31, 32, 34, and 35 were used to evaluate the fourth criterion. The third criterion was evaluated by means of the individual student problem projects. In Table II the value of Y_{1i} is the score for the individual for the first objective; the value of Y_{2i} is the score for the individual for the second objective; the value of Y_{4i} is the score for the individual for the fourth objective; the value of $T_{.j}$ is the total raw test score for the individual; the value of $T_{i.}$ is the number of students answering the particular item correctly.

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[1]Harold Gulliksen, Theory of Mental Tests (New York: John Wiley and Sons, Inc., 1950), pp. 363-94.

TABLE II

ITEM SCORES, CRITERION SCORES, AND TOTAL SCORES FOR THE EXPERIMENTAL GROUP ON A TEST OF GENERAL PROFICIENCY IN ELEMENTARY STATISTICAL INFERENCE, FORM B, PARTS I AND II

STUDENT	STATISTICS TEST ITEM NUMBER																																			CRITERION SCORE			TOTAL SCORE
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	$Y_{1.}$	$Y_{2.}$	$Y_{4.}$	$T_{.j}$
1	1	1	1	1	1			1	1	1						1	1		1	1	1	1	1			1	1			1						10	4	4	18
2	1				1	1		1	1	1					1	1	1	1	1	1		1	1	1	1		1		1			1	1			10	3	7	20
3	1	1	1	1	1	1	1	1		1				1		1	1	1	1	1	1		1	1				1			1				1	12	5	4	21
4	1	1	1	1	1	1		1	1		1			1		1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1				13	7	6	26
5	1	1	1				1		1	1	1		1			1	1	1	1	1	1	1	1	1		1	1					1		1		11	5	5	21
6	1	1	1	1	1	1	1					1				1	1	1					1	1	1		1			1						11	2	3	16
7	1		1	1	1	1	1	1	1		1				1			1	1	1	1	1	1	1	1			1				1				11	4	5	20
8	1	1		1	1	1	1	1	1		1					1	1	1	1	1	1	1		1	1	1	1	1	1	1	1					12	5	7	24
9	1	1	1	1	1	1	1	1		1			1		1	1	1	1		1	1	1				1					1	1	1	1	1	12	6	5	23
10	1		1		1	1	1	1	1	1	1			1		1	1	1	1	1			1	1	1	1		1				1	1			12	5	5	22
11	1	1		1		1			1		1		1		1	1	1	1	1				1	1	1						1					10	2	4	16
12	1	1	1	1	1	1		1		1	1	1	1	1		1	1	1	1	1	1	1		1			1	1	1	1	1		1			15	4	7	26
13	1	1	1	1	1	1	1		1	1	1					1	1	1	1	1	1	1	1		1	1			1	1	1		1			11	5	8	24
14	1	1	1	1		1		1				1				1	1	1	1			1		1	1	1	1								1	10	2	5	17
15	1	1	1		1		1	1								1	1	1	1	1	1	1	1				1	1	1						1	8	4	6	18
16	1	1	1	1	1	1	1		1							1	1	1	1	1	1	1	1		1			1	1	1	1		1			9	5	8	22
17	1	1	1	1	1		1	1		1	1	1		1		1	1	1	1	1	1		1	1	1	1		1	1	1		1		1		13	7	6	26
18		1	1	1			1		1		1	1				1	1	1	1	1	1	1		1	1	1	1		1				1	1		10	3	8	21
19	1	1	1	1	1		1	1	1	1		1	1			1	1	1	1	1	1	1	1			1	1	1	1			1		1		13	6	6	25
$T_{1.}$	18	16	16	15	15	13	13	13	12	10	10	6	5	5	4	18	18	18	17	16	14	14	14	13	11	11	11	10	10	8	8	8	7	5	4				

The formula used for test validity was

$$r_{xy} = \frac{\sum_{g=1}^{K} r_{yg} s_g}{\sum_{g=1}^{K} r_{xg} s_g}$$

and the formula used for test reliability was

$$r_{xx} = \left[\frac{K}{K-1}\right]\left[1 - \frac{\sum_{g=1}^{K} s_g^{2}}{\left(\sum_{g=1}^{K} r_{xg} s_g\right)^{2}}\right]$$

where in these equations

K, is the number of items in the test,

s_g^{2}, is the variance of item g [i.e., $s_g^{2} = p_g(1 - p_g)$],

$r_{xg} s_g$, the item reliability index, is the point-biserial item--test correlation multiplied by the item standard deviation,

$r_{yg} s_g$, the item validity index, is the point-biserial item--criterion correlation multiplied by the item standard deviation.

To compute the values for $r_{xg} s_g$ and for $r_{yg} s_g$ the following formulas were used:

$$r_{xg} s_g = \frac{N \sum_{i=1}^{N_g} X_{ig} - N_g \sum_{i=1}^{N} X_i}{N \sqrt{N \sum_{i=1}^{N} X_i^{2} - \left(\sum_{i=1}^{N} X_i\right)^{2}}}$$

$$r_{yg}s_g = \frac{N\sum_{i=1}^{N_g} Y_{ig} - N_g \sum_{i=1}^{N} Y_i}{N\sqrt{N\sum_{i=1}^{N} Y_i^2 - \left(\sum_{i=1}^{N} Y_i\right)^2}}$$

In these equations

N, is the total number of students taking the test,

N_g, is the number of students answering item g correctly ($g = 1 \ldots K$),

X_i, is the test score for the individual ($i = 1 \ldots N$),

Y_i, is the criterion score for individual i ($i = 1 \ldots N$),

X_{ig}, is the test score for each person answering item g correctly,

Y_{ig}, is the criterion score for each person answering item g correctly.

The value for r_{xx} was found to be 0.402 which was significant at the 5 per cent level. The value for r_{xy_1} was found to be 0.498, for r_{xy_2} the value was 0.424, for r_{xy_4} the value was 0.447. All of these were significant at the 5 per cent level.

The 1948 edition of the ACE Psychological Examination for College Freshmen[2] and the College Qualification Test, Test N, Mathematics,[3] was administered to each of the students in the experimental group. The results of these tests are given in Table III, Personal Data for Individuals in the Experimental Group.

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[2] American Council on Education Psychological Examination for College Freshmen (1948 ed.; Princeton, New Jersey: Cooperative Test Division, Educational Testing Service, 1948).

[3] College Qualification Test, Test N, Mathematics, Form B (New York: Psychological Corporation, 1955-56).

TABLE III

PERSONAL DATA FOR INDIVIDUALS IN THE EXPERIMENTAL GROUP

Student	ACE Psychological Examination: Raw Score Q	L	Total	Percentile: Four-Year Colleges: Men Q	L	Women Q	L	Overall Q	L	All Colleges: Men Q	L	Women Q	L	Overall Q	L	Total	College Qualification Test N Mathematics: Raw Score	Percentile (Univ. of Tenn. Norm)	Age	Classification
1	68	94	162	99+	94			99+	94	99+	96			99+	95	99	49	99+	17	Junior
2	62	88	150	97	90			98	89	98	92			99	91	96	48	99+	17	Junior
3	59	54	113	95	25			96	24	96	30			97	28	61	49	99+	17	Senior
6	37	71	108	27	64			33	62	31	68			37	66	53	36	80	17	Senior
8	48	69	117	70	60			76	57	73	64			79	62	67	44	94	17	Senior
9	52	58	110	82	34			87	32	85	38			89	37	56	48	99+	17	Senior
14	53	67	120	85	55			89	52	87	59			71	91	57	47	99	17	Senior
16	57	84	141	92	86			94	85	94	88			95	87	92	49	99+	17	Senior
17	50	74	124	76	70			82	68	80	74			84	72	77	49	99+	17	Senior
18	50	76	126	76	74			82	72	80	77			84	75	79	49	99+	17	Senior
19	48	51	99	70	20			76	19	73	24			79	23	39	47	99	17	Senior
4	51	76	127			79	69	84	72			82	73	87	75	80	49	99+	16	Junior
5	60	67	127			99	50	97	52			99+	55	98	57	80	42	90	17	Senior
7	52	85	137			92	84	87	86			93	87	89	88	90	43	92	17	Senior
10	61	77	138			99+	71	98	74			99+	75	98	77	90	48	99+	17	Senior
11	59	70	129			98	57	96	60			99	62	97	64	82	46	98	16	Junior
12	56	79	135			96	75	93	77			97	78	94	80	88	42	90	17	Senior
13	56	66	122			96	48	93	50			97	53	94	55	74	47	99	17	Senior
15	53	76	129			93	64	89	66			94	68	91	70	82	46	98	17	Senior

The test instrument, A Test of General Proficiency in Elementary Statistical Inference, was administered to the experimental group and to the control group, using Form A for the pre-test and Form B for the post-test. The scores were corrected for guessing by use of the formula

$$CS = R - \frac{W}{n - 1}$$

where

CS, is the corrected score,

R, is the number of items in parts I and II which were marked correctly (raw score),

W, is the number of items in Parts I and II which were marked incorrectly,

n, is the number of choices in the item.

Table IV, Total Scores on Parts I and II of A Test of General Proficiency in Elementary Statistical Inference for the Experimental Group, gives the results of the tests for the experimental group and Table V, Total scores for Parts I and II of A Test of General Proficiency in Elementary Statistical Inference for the Control Group, gives the results of the tests for the control group. The t-test for paired data was used to determine whether or not a significant difference occurred between the scores on the pre-test and on the post-test. The t-score for the experimental group was 9.228 which was significant at the 0.001 level of significance. The t-score for the control group was found to be -0.415 which was not significant at the 0.05 level of significance.

Product-moment coefficients of correlation were obtained to determine the relationship between the Q-score on the ACE Psychological

TABLE IV

TOTAL SCORES ON PARTS I AND II OF A TEST OF GENERAL PROFICIENCY IN ELEMENTARY STATISTICAL INFERENCE FOR THE EXPERIMENTAL GROUP

Student Number	Test A Raw Scores	Test A Corrected Scores	Test B Raw Scores	Test B Corrected Scores	Difference
1	18	13.00	18	23.33	10.33
2	20	15.50	20	19.33	3.83
3	9	1.25	21	13.08	11.83
4	5	- 3.75	26	23.42	27.17
5	10	2.67	21	12.92	10.25
6	11	3.92	16	17.00	13.08
7	13	6.58	20	15.67	9.09
8	8	0.08	24	20.75	20.67
9	13	6.50	23	10.25	3.75
10	15	9.17	22	18.08	8.91
11	10	2.58	16	22.00	19.42
12	12	5.17	26	16.92	11.75
13	10	2.67	24	11.67	9.00
14	11	4.08	17	16.75	12.67
15	11	3.83	18	20.83	17.00
16	8	0.08	22	18.25	18.17
17	12	5.25	26	23.25	18.00
18	13	6.50	21	15.42	7.58
19	10	2.67	25	10.25	7.58
				Total	241.42
				Average Difference	12.71
				s_d	6.002

TABLE V

TOTAL SCORES ON PARTS I AND II OF A TEST OF GENERAL PROFICIENCY IN ELEMENTARY STATISTICAL INFERENCE FOR THE CONTROL GROUP

Student Number	Test A Scores Raw	Test A Scores Corrected	Test B Scores Raw	Test B Scores Corrected	Difference
1	10	2.67	7	- 1.42	- 4.09
2	10	2.42	12	5.25	2.83
3	16	10.33	9	1.25	- 9.08
4	4	- 5.25	7	- 1.25	4.00
5	13	6.50	6	- 2.75	- 9.25
6	15	9.00	10	2.67	- 6.33
7	15	9.33	8	- 0.08	- 9.41
8	18	13.08	10	2.50	-10.58
9	7	- 1.25	8	- 0.17	1.08
10	12	5.25	11	4.00	- 1.25
11	10	2.50	11	3.92	1.42
12	15	9.08	7	- 1.25	-10.33
13	10	2.67	12	5.33	2.67
14	5	- 4.00	7	- 1.42	3.58
15	12	5.00	10	2.58	- 2.42
16	11	3.67	8	- 0.08	- 3.75
17	7	- 1.42	7	- 1.42	0.00
18	7	- 1.25	15	9.08	10.33
19	5	- 4.08	9	- 1.17	2.91
20	9	1.25	11	3.92	2.67
21	5	- 3.92	12	5.25	9.17
22	7	- 1.50	11	3.83	5.33
23	12	5.33	10	2.58	- 2.75
24	4	- 5.25	10	2.50	7.75
25	5	- 3.83	9	1.25	5.08
26	7	- 1.17	13	6.42	7.59
27	9	1.33	10	2.67	1.34
28	11	3.67	11	3.83	0.16
29	13	6.58	9	1.25	- 5.33
30	9	1.25	4	- 5.08	- 6.33
31	7	- 1.17	7	- 1.33	- 0.16
				Total	-13.15
				Average Difference	- 0.424
				s_d	5.776

Examination and the raw score of the individual student on the post-test, the Q-score and the score on the College Qualification Test, the L-score on the ACE Psychological Examination and the raw score of the individual student on the post-test. The values for r were found to be 0.155, 0.498, and 0.646, respectively. The last two of these values were found to be significant at the 5 per cent level of significance.

To evaluate the development of the ability to utilize various statistical techniques in the critical analysis of problems, Part III was used with both the experimental group and with the control group. The control group was unable to solve any of the problems in either the pre-test or the post-test. The experimental group was unable to solve any of the problems on the pre-test. The results of this part of the post-test are given in Table VI, Item Scores and Total Scores For the Experimental Group on A Test of General Proficiency in Elementary Statistical Inference, Form B, Part III. The scores given in this table are for a total value of forty-six points. The point values for each item were arbitrarily assigned by setting certain check points in the solution of the problem. These arbitrary point values for each problem are listed in the table in parentheses under the number of the problem or item.

To evaluate the third objective or criterion as listed in Chapter II, each of the students selected a problem of his own choosing. The student was required to state the problem, state the hypotheses, select the sample, gather the data, analyze the data, and draw conclusions. The result of the student's investigation was then presented in the form of a

TABLE VI

ITEM SCORES, AND TOTAL SCORES FOR THE EXPERIMENTAL GROUP ON A TEST OF GENERAL PROFICIENCY IN ELEMENTARY STATISTICAL INFERENCE, FORM B, PART III

Student Number	Item 36 (2)	37 (3)	38a (12)	38b (8)	38c (9)	38d (7)	38e (5)	Total Score (46)
1	2	2	11	8	9	5	5	42
2	2	3	10	8	7	7	5	42
3	2	3	8	8	9	4	4	38
4	2	3	11	6	2	7	0	31
5	2	3	11	8	8	5	2	39
6	2	2	10	0	9	7	5	35
7	2	3	10	6	9	6	4	40
8	2	3	5	4	6	5	0	25
9	2	2	11	7	9	7	4	42
10	2	2	10	8	8	5	4	39
11	2	3	11	6	7	6	3	38
12	2	3	8	0	7	6	4	30
13	2	3	8	7	8	6	3	37
14	2	1	11	8	7	5	0	33
15	2	3	11	7	9	7	4	43
16	2	3	11	5	5	3	1	30
17	2	3	9	5	9	7	4	39
18	2	1	12	6	0	0	0	21
19	2	3	0	0	0	0	0	5
Average	2	2.58	9.37	5.63	6.74	5.16	2.74	34.16
Standard Deviation	0	0.69	2.81	2.78	2.96	2.14	1.93	9.31

paper. The following list indicates the titles of the papers submitted by the students.

"Comparison of Attendance at a Certain Theater on Days of Good Weather as Compared to Days of Bad Weather in 1957"

"An Estimation of the Number of Automobiles the Average American Family Owns"

"A Study of the Effect of Personal Bias in the Estimation of a Person's Golf Score"

"A Study of the Relationship Between the Number of Students and the Number of Teachers in the State Universities of the United States"

"Children, Telephones, Television: Related or Not Related!"

"An Estimate of the Population of Knox County Based Upon A Random Sample"

"A Study to Determine Whether or not Bearden High School has the Same Percentage of Left-Handed People as the National Average"

"A Study of the Probability Involved in the Game of Poker"

"A Statistical Study of the Relationship Between the Causes of Death in Knox County and in the State of Tennessee for the Year 1957"

"A Statistical Test of the Theory That People are Affected by the Subconscious in Their Choice of Numbers"

"A Study of the Relationship Between the Preference and Ownership of Colored or Conventional Telephones"

"A Study to Determine the Truthfulness of Advertisement in a Local Grocery Store"

"Determination of the Mean Amount of Fluid Contained in a Particular Brand of Bottled Soft Drink"

"Do Advertised Weights of Produce Lie?"

"A Study of the Sacking Distribution of Apples"

"A Comparison Study of the Mean Number of Children Per Family in Knoxville and the Nation"

"A Study to Determine the Better Golf Course as Indicated by Golf Scores"

"A Study of the Comparison of Intelligence Scores for the Various Classes at Bearden High School as Compared to a National Norm"

"A Comparison of Theoretical and Empirical Probability"

In these papers the statistical procedures used by the students and the frequency of occurrence were:

t-test for difference between two means	4
t-test for a single hypothesized mean value	7
Confidence interval estimate of the true difference between two population means	2
Test of hypothesis concerning the dependency of variables	1
Product-moment coefficient of correlation	1
Analysis of variance	2
Chi-square test for goodness of fit	1
Test of hypothesis about single population proportion	1
Test of hypothesis about difference between two population proportions	2
Chi-square test for equality of more than two population proportions	2
Hypergeometric distribution	1
F-test for equality of two population variances	2
Frequency polygon	4
Histogram	2
Ogive	1

Several examples of the problems attacked by the students are given in Appendix C in the same manner as presented for the class.

CHAPTER IV

SUMMARY AND CONCLUSIONS

The purpose of this study was to determine the ability of apt secondary school students to apply principles of elementary probability and statistical inference in the analysis of data following a semester of instruction in statistics and elementary probability.

The test hypotheses for this study were:

1. There is no significant difference between the pre-test scores and the post-test scores for the experimental group.

2. There is no significant difference between the pre-test scores and the post-test scores for the control group.

3. There is no significant difference in the ability of apt secondary school students who have completed a semester of elementary probability and statistical inference and that of apt secondary school students who have not received instruction in elementary probability and statistical inference in applying the concepts and principles related to this course, as measured by post-test scores.

A one semester course-of-study in elementary probability and statistical inference was developed which included discussion of:

1. The Components of a Statistical Investigation
2. Measures of Central Tendency and Variability
3. Elementary Probability
4. Discrete Distribution Functions

5. The Normal Distribution

6. Tests of Hypotheses

7. Developing the Statistical Report

A testing instrument, A Test of General Proficiency in Elementary Statistical Inference, was developed. This test was subdivided into three parts:

1. Selection of the appropriate method for testing stated hypotheses or stated problems.

2. General questions concerning the principles of probability and statistical inference.

3. Mathematical solution of statistical problems

A group of nineteen secondary school students were used as the experimental group and a group of thirty-one students in a Plane Geometry class were used as the control group. The experimental class was composed of four juniors and fifteen seniors. The evaluative instrument was administered to both the experimental and the control groups at the beginning and the end of the period of instruction. Different forms were used for each time.

Analysis of the post-test scores for validity and reliability of the testing instrument gave significant coefficients of correlation in both cases. This evidence supports the belief that the instrument is both valid and reliable.

Analysis of the data for differences between pre-test and post-test scores after correction for guessing resulted in a very highly significant t-score for the experimental group. The first test hypothesis was rejected.

Analysis of the data for differences between pre-test and post-test scores after correction for guessing resulted in a non-significant t-score for the control group. The second test hypothesis was accepted.

Comparison of the sample mean difference scores for the two groups indicates a significant difference between the mean score for the control group and for the experimental group. The third test hypothesis was rejected.

The results of this study support the belief that apt secondary school students are able to apply the principles of elementary probability and statistical inference following a semester of instruction in elementary probability and statistical inference.

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APPENDIX A

A TEST OF GENERAL PROFICIENCY IN ELEMENTARY STATISTICAL INFERENCE

FORM A

Part I. Indicate on the answer sheet which of the named procedures would be most applicable in testing the following hypotheses or solving the stated problem.

a. t-test
b. χ^2-test
c. Analysis of Variance
d. Correlation
e. Regression

1. A significant difference does not exist between the average gas mileage of four different makes of automobiles.

2. The average reaction time of Reagent A is at least as great as that of Reagent B.

3. Information was needed concerning the relationship between two variables.

4. It is desired to determine whether or not a series of samples from a certain production line agree with a predicted distribution.

5. It is desired to estimate the sales potential of a prospective salesman based upon his score on a personality test.

6. In the following table X is milligrams of nicotine in smoke of filter cigarettes; Y is milligrams of tar in smoke of filter cigarettes. Is there a significant relationship between the two?

X	Y
0.6	11.8
1.6	16.5
1.6	17.2
1.6	24.1
1.7	25.2
1.8	20.6
1.8	22.8
2.0	22.4
2.3	19.4
2.6	20.6

7. The variability in two classes as determined by achievement tests is identical.

8. The coefficient of elasticity is the same for a set of springs before and after treatment with acid.

9. The proportion of defective spools of yarn will be the same for three machines.

10. Random samples of 200 parts from each of three manufacturers showed the following numbers of defective and non-defective parts:

Manufacturer	Defective Parts	Non-defective Parts
A	30	170
B	14	186
C	16	184

Is it possible that the true proportions of defective parts made by the three manufacturers are the same?

11. Success in college may be predicted on the basis of scores on entrance examinations.

12. It is believed that the average cigarette consumption of the American public is 10 cigarettes per day per person with a variance of 16. A sample of 100 individuals was taken and the average cigarette consumption per day per person was found to be 8 cigarettes. Is it reasonable to suppose that this sample represented a population smoking a smaller number of cigarettes per day?

13. A commercial producer of alcohol runs tests on 10 two-ounce specimens of his product to determine the concentration. He finds the average concentration to be 90 per cent with a standard deviation of 6 per cent. Are these findings compatible with the belief that the actual concentration is 94 per cent?

14. Frozen peaches prepared by four different methods will not vary in taste if four different syrup compositions are used.

15. The tensile strength of a rubber vulcanizing process shows the following variations with different conditions of production. Data are in pounds per square inch.

Cure at 140^{o} (Minutes)	Accelerators A	Accelerators B	Accelerators C
40	3700	4300	3900
60	3900	4200	4100
80	3600	4300	4000

Do the accelerators or cure times have different effects upon the tensile strength of the process?

Part II. Select the most appropriate answer from the choices given and mark the corresponding letter on the answer sheet.

16. The difference between Brown's scores on two statistics tests was 20 points. The standard deviation on the first test was 15 and on the second test 10.

    a. Smith did better on the first test than on the second test.
    b. Smith did better than Brown on both tests.
    c. Insufficient data are given for making any decision regarding the relationship between Brown's scores and Smith's scores.
    d. Brown passed both of the tests.

17. A graph showing the number of individuals possessing a certain quality would be called a (an)

    a. histogram.
    b. ogive.
    c. cumulative frequency distribution.
    d. frequency distribution.

18. The power of a test is an expression of the probability of

    a. rejecting a hypothesis, true or false.
    b. rejecting a true hypothesis.
    c. accepting a true hypothesis.
    d. accepting a false hypothesis.

19. The normal curve is a graphic demonstration of the fact that in a population of individuals possessing a common trait,

    a. a greater percentage tend to be alike rather than different.
    b. a greater percentage tend to be different rather than alike.
    c. there is equal chance for any form of this trait to appear.
    d. the probability of finding a deviate is low.

20. Which of the following is an expression of the limits of the normal curve?

    a. $-\infty$ to a
    b. 0 to ∞
    c. $-\infty$ to 0
    d. $-\infty$ to ∞

21. Variances are computed for two samples drawn from two sources and are found to be equal. It may be concluded that

a. both sources have the same population variance.
b. both sources may have the same population variance.
c. both populations have the same parameters.
d. both populations may have the same parameters.

22. If the probability that any person thirty years old will be dead within a year is p = 0.01, the probability that no more than one person in ten of this age will die within one year is

a. 0.90.
b. 0.95.
c. 0.995.
d. 0.999.

23. Which one of the following would not be normally distributed?

a. The number of physically defective children born in 100 hospitals in one year.
b. The weights of fifty adult male albino rats.
c. The typing speeds of fifty stenographers.
d. The golf scores of the members of a given club in a particular year.

24. If the mean I.Q. of children is approximately 100 with a standard deviation of 16, approximately how many in 1000 will have I.Q.'s above 116? Assume a "bell shaped" distribution.

a. 130
b. 140
c. 150
d. 160

25. Which one of the following terms would best describe the type of sample one would get by using the table of random numbers?

a. Selective
b. Stratified
c. Biased
d. Unbiased

26. A z-score of 0 on a test would indicate which of the following conditions in describing the student's placement with respect to the remainder of the class?

a. Below average
b. Average
c. Above average
d. Superior

27. In the process of matching coins, a coin turns heads nine times out of ten. The probability that the coin will turn up heads on the tenth toss is

a. 9/10.
b. 7/10.
c. 5/10.
d. 3/10.

28. If a distance of 2.326 sigma is laid off on each side of the mean, this range will include what per cent of the cases in a normal distribution?

a. 85 per cent
b. 90 per cent
c. 95 per cent
d. 99 per cent

29. Commission of the Type II error is found when

a. action is not taken when it should not be taken.
b. action is not taken when it should be taken.
c. action is taken when it should not be taken.
d. action is taken when it should be taken.

30. The value appearing most frequently in a frequency distribution is called the

a. arithmetic mean.
b. mode.
c. median.
d. geometric mean.

31. The distribution resulting from the plotting of sample variances coming from a population having a common variance is the

a. χ^2-distribution.
b. hypergeometric distribution.
c. normal distribution.
d. Student-t distribution.

32. The best protection against accepting a false hypothesis where the mean is in reality greater than the hypothecized mean would be given by use of

a. test Type a.
b. test Type b.
c. test Type c.
d. test Type d.

33. When five coins are tossed, the probability that either two or four heads will show is

a. 13/32.
b. 14/32.
c. 15/32.
d. 16/32.

C

34. When sampling without replacement from a finite dichotomous population of small number, which of the following distributions is applicable?

a. Poisson distribution.
b. Binomial distribution.
c. Normal distribution.
d. Hypergeometric distribution.

A

35. Which of the following is an assumption basic to the use of parametric statistical techniques?

a. Normality of distribution.
b. Independence of variables.
c. Randomness of sample.
d. All of these.

D

Part III. Solve the following problems.

36. Before buying a batch of forty fuses a man tests three. The batch contains four defective fuses. Write a formula for the frequency function f (x) [where x is the number of defectives] for drawing exactly one defective fuse in the sample.

37. Assuming that boy and girl births are equally likely, the probabilities that a family of exactly three children will have no boys, one boy, two boys, or three boys are 1/8, 3/8, 3/8, and 1/8 respectively. Observations on 400 families having three children each gave the following data:

No. of boys	0	1	2	3
Frequency	58	155	142	45

Are these data consistent with the theoretical distribution?

38. Twenty per cent of people contracting a certain disease do not recover. Write a formula for the frequency function f (x) where x is the number of persons out of 10 contracting the disease who do not recover.

39. In making glass bottles some bottles contain "stones" (small pieces of refractory or other non-glassy inclusions). If the average number

of stones per bottle is 0.26, calculate the probability that a bottle will contain at least two stones. Compute to three decimal places.

40. In the process of testing two new types of floating smoke pots, it was desired to know if there was a real difference between the average burning times of the two new types of pots. The following data were collected and each value was coded by subtracting 600 from the original value.

Type I	Type II
-15	60
15	30
0	105
0	105
-45	-75
-30	-60
-5	75
-105	-105
15	-30
60	

Sum of values for type I = -110
Sum of values for type II = 105
(Sum of values for type I)^2 = 12,100
(Sum of values for type II)^2 = 11,025
Sum of squares of values for type I = 18,250
Sum of squares of values for type II = 53,325

41. In a particular school district it was desired to know if there was any relationship between the amount of space allotted for playgrounds and the number of accidents to children. Eighteen districts were used in the gathering of data with the following results obtained:

District	Proportion of open space used for playground (x)	Proportion of accidents to children as percentage of all accidents (y)
1	5.0	46.3
2	2.2	43.4
3	1.3	42.9
4	4.2	42.2
5	1.4	40.0
6	2.0	38.8
7	7.0	38.2
8	2.5	37.4
9	4.5	37.0
10	3.1	33.3
11	5.2	33.6
12	7.2	33.6
13	6.3	30.8
14	12.2	28.3
15	14.6	23.8
16	23.6	17.8
17	14.8	17.1
18	27.5	10.8

Sum of x's = 144.6
Sum of x-squares = 2153.06
Sum of y's = 595.3
Sum of y-squares = 21389.61
Sum of xy's = 3597.80
(Sum of x's)^2 = 20909.16
(Sum of y's)^2 = 354382.09

Does a significant relationship exist?

APPENDIX B

A TEST OF GENERAL PROFICIENCY IN ELEMENTARY

STATISTICAL INFERENCE

FORM B

Part I. Of the named procedures, select the one which is most applicable in testing the following hypotheses or solving the stated problem and mark the appropriate letter on the answer sheet.

a. z-test
b. Analysis of Variance
c. χ^2-test
d. t-test
e. Correlation

1. There is no relationship between the amount of nicotine and the amount of tars in tobacco.

2. Intelligence does have some effect upon success in college.

3. There is an inverse relationship between the age of a plant and the effectiveness of certain types of nutrient materials.

4. The quality of a product is in direct ratio to the amount of time spent in production.

5. The height in inches (coded) of three different racial groups for samples of three each are as indicated below. Is there evidence of stature variation among these groups?

A	B	C
2	1	4
5	2	3
3	1	2

6. A standardized test of ability to do scientific thinking has been administered numerous times and has an average score of 80 with a standard deviation of 10. In one group of 25 students special emphasis on interpretation of data, drawing inferences and other aspects of scientific thinking have been stressed. In this group of 25 students a mean of 85 was obtained. Is there reason to believe that the special instruction changes the results on the test?

7. Neither education nor experience has a significant effect on the effectiveness of a salesman.

8. The malleability of a particular metal is the same before and after the "curing" process.

9. Physicians indicate that one-half of the offspring of families in which one of the parents is diabetic will be diabetic. If, in a sample of 80 children from such families, 35 are diabetic, do you accept the physicians' claim?

10. Diet A and Diet B have different effects on the body weights of a specific breed of animals.

11. Two laboratories carry out independent tests of fat content for ice cream by a certain manufacturer. A sample is taken from each batch, halved, and the separate halves sent to the respective laboratories. The results obtained on the ten batches were as follows:

Batch	1	2	3	4	5	6	7	8	9	10
Lab A	7.2	8.5	7.4	3.2	8.9	6.7	9.4	4.6	7.7	6.9
Lab B	9.1	8.5	7.9	4.3	7.4	7.7	9.3	6.6	6.8	6.7

Can the differences between the analyses be attributed to chance?

12. A particular chemical does not increase the germination percentage for seeds of a particular plant.

13. Three microanalytical determinations of carbon in ephedrine hydrochloride are made by three different techniques with the following results:

Technique A: $\bar{X} = 0.00982$
Technique B: $\bar{X} = 0.00676$
Technique C: $\bar{X} = 0.00491$

The total "pooled" variance estimate is 5.138×10^{-7}. Is there reason to believe that the three techniques are different in their results?

14. The percentage of defective parts produced in a particular department by two different machines is the same.

15. A study was made to determine whether there was any relationship between a person's educational level and his opinion as to the motivation of conscientious objectors. A random sample of 300 individuals was chosen. Of the 120 people who had finished college, 70 thought that the men were cowards and the rest did not. Of the individuals who had not finished college 50 thought that the men were not cowards and the rest thought that they were. Does educational level have any effect upon the person's opinion as to motivation of conscientious objectors?

Part II. Select the most appropriate answer from the choices given and mark the corresponding letter on the answer sheet.

16. Which of the following is an expression of the limits of the χ^2-distribution?

a. $-\infty$ to α
b. 0 to ∞
c. $-\infty$ to 0
d. $-\infty$ to ∞

17. Data may be measured for goodness-of-fit to a prescribed distribution by use of the

a. Student-t distribution
b. F-distribution
c. χ^2-distribution
d. $\frac{\chi^2}{d.f.}$ distribution

18. If a distance of 2.575 standard deviations is laid off on each side of the population mean, this range will include what per cent of the cases in a normal distribution?

a. 85 per cent
b. 90 per cent
c. 95 per cent
d. 99 per cent

19. The type II error is an expression of the probability of

a. rejecting the hypothesis, true or false.
b. rejecting a true hypothesis.
c. accepting a true hypothesis.
d. accepting a false hypothesis.

20. When sampling from a normally distributed population, the probability is

a. low for drawing a value which is near that of the population mean.
b. high for drawing a value which is not near that of the population mean.
c. the same for the drawing of all variables.
d. low for drawing a value from the population which is an extreme deviate.

21. If an item appears within the limits of $\mu \pm 1.5\sigma$, the occurrence may be said to be

   a. usual.
   b. significant.
   c. highly significant.
   d. very highly significant.

22. Means are computed from two samples drawn from two sources and are found to be equal. It may be concluded that

   a. both sources may have the same population mean.
   b. both sources have the same population mean.
   c. both sources may have the same population parameters.
   d. both sources have the same population parameters.

23. In throwing a pair of true dice the probability of getting a seven or eleven is

   a. 1/9
   b. 2/9
   c. 3/9
   d. 4/9

24. The relationship between two variables is measured by the

   a. regression line.
   b. slope of the regression line.
   c. coefficient of correlation.
   d. coefficient of variation.

25. Commission of the Type I error is found when

   a. action is taken when it should not be taken
   b. action is taken when it should be taken
   c. action is not taken when it should not be taken
   d. action is not taken when it should be taken

26. The value which divides a frequency distribution into two equal parts is called the

   a. arithmetic mean.
   b. median.
   c. mode.
   d. harmonic mean.

27. When sampling with replacement from a large population ($N>100$) and the probability of the event is small ($p<0.05$), which of the following distributions is applicable?

a. Binomial
b. Poisson
c. Normal
d. Hypergeometric

28. Measurements of objects in general result in values that may be said to be

a. qualitative in nature.
b. quantitative in nature.
c. continuous in nature.
d. discrete in nature.

29. The best protection against accepting a false hypothesis where the mean is in reality less than the hypothesized mean would be given by use of

a. test Type a.
b. test Type b.
c. test Type c.
d. test Type d.

30. Which one of the following would not be normally distributed?

a. The coefficients of correlation for 50 samples drawn from the same source.
b. The proportion of defective parts for 50 samples drawn from a given production line.
c. The F-ratios from 50 samples drawn from each of two given populations.
d. The distribution of dependent variables for a given value of the independent variable.

31. If the mean I.Q. of children is approximately 100 with a standard deviation of 16, approximately how many in 1000 would have an I.Q. above 131? Assume a "bell-shaped" distribution.

a. 20
b. 25
c. 30
d. 35

32. Which of the following is not an assumption basic to the use of parametric statistical techniques?

a. Normality of distribution
b. Knowledge of the population variability
c. Independence of variables
d. Randomness of sample

33. A z-score of 1.75 on a test would indicate which of the following conditions in describing the student's placement with respect to the remainder of the class?

a. Below average
b. Average
c. Above average
d. Superior

34. A graph showing the cumulative percentage of individuals possessing a certain quality would be called a (an)

a. histogram.
b. ogive.
c. frequency distribution.
d. cumulative frequency distribution.

35. If the probability that any person thirty years old will be dead within a given year is $p = 0.01$, the probability that no more than one person in a group of 10 of this age will survive a given year is:

a. 989×10^{-20}
b. 990×10^{-20}
c. 991×10^{-20}
d. 992×10^{-20}

Part III. In the accompanying booklet, show all of the necessary computations, indicating in all cases the assumptions being used, hypotheses being tested, critical regions, and decision rules.

36. Suppose that the number of calls a telephone operator receives from 9:00 to 9:05 follows a Poisson distribution with $\mu = 3$. Find the probability that the operator will receive no calls in that time interval tomorrow.

37. Before buying a batch of sixty fuses a man tests six. The batch contains eight defective fuses. Write a mathematical expression for the frequency function f(x) [where x is the number of defectives] for drawing exactly one defective fuse in the sample.

38. Using the data given in the accompanying tables,[1] show all work involved in testing the following hypotheses or in obtaining the desired information.*

a. There are no significant differences between scores, taking together the four characteristics (using the composite scores) for the different methods of preparing fish.

b. A significant relationship does not exist between the moisture content and aroma of the fish.

c. A significant difference does not exist between the scores for flavor and aroma for the fish.

d. A significant difference does not exist between the variability of the methods A and B.

e. If the moisture content of the fish is 6.1, what is your best point estimate of the aroma score for the fish on the average.

Method Used in the Study

Three lots of fish of twelve each were prepared by methods A, B, and C. Five experienced judges ate samples of each fish and graded each for aroma, flavor, texture, and moisture. The average score for aroma for the five judges was recorded as the aroma score for the particular fish. Similarly averages of the judges' scores were used for flavor, texture, and moisture. In this way individual differences between judges were somewhat ironed out of the results. Judges were not aware of the methods of preparing the fish and never knew which preparation was used for any particular sample.

---

[1] Baten, W. D., Tack, Pa Ia, Baeder, Helen A., "Testing for Differences Between Methods of Preparing Fish by Use of a Discriminant Function," Industrial Quality Control 14(7): 6-10.

*Assume: 1) Common variance where necessary; 2) dependency; 3) linearity of data.

	Method												Composite Method Scores		
	A				B				C						
	Aroma	Flavor	Texture	Moisture	Aroma	Flavor	Texture	Moisture	Aroma	Flavor	Texture	Moisture	A	B	C
	5.4	6.0	6.3	6.7	5.0	5.3	5.3	6.5	4.8	5.0	6.5	7.0	4.05	3.31	2.16
	5.2	6.2	6.0	5.8	4.8	4.9	4.2	5.6	5.4	5.0	6.0	6.4	5.04	3.39	2.26
	6.1	5.9	6.0	7.0	3.9	4.0	4.4	5.0	4.9	5.1	5.9	6.5	3.45	2.24	2.74
	4.8	5.0	4.9	5.0	4.0	5.1	4.8	5.8	5.7	5.2	6.4	6.4	3.57	3.93	2.35
	5.0	5.7	5.0	6.5	5.6	5.4	5.1	6.2	4.2	4.6	5.3	6.3	4.23	3.37	2.42
	5.7	6.1	6.0	6.6	6.0	5.5	5.7	6.0	6.0	5.3	5.8	6.4	4.23	3.21	2.61
	6.0	6.0	5.8	6.0	5.2	4.8	5.4	6.0	5.1	5.2	6.2	6.5	4.18	2.35	2.72
	4.0	5.0	4.0	5.0	5.3	5.1	5.8	6.4	4.8	4.6	5.7	5.7	4.35	2.59	2.18
	5.7	5.4	4.9	5.0	5.9	6.1	5.7	6.0	5.3	5.4	6.8	6.6	3.88	4.48	2.74
	5.6	5.2	5.4	5.8	6.1	6.0	6.1	6.2	4.6	4.4	5.7	5.6	3.02	3.93	1.93
	5.8	6.1	5.2	6.4	6.2	5.7	5.9	6.0	4.5	4.0	5.0	5.9	4.56	3.43	1.32
	5.3	5.9	5.8	6.0	5.1	4.9	5.3	4.8	4.4	4.2	5.6	5.5	4.37	3.13	1.72
ΣX	64.6	68.5	65.3	71.8	63.1	62.8	63.7	70.5	59.7	58.0	70.9	74.8	48.93	39.36	25.82
$\bar{X}$	5.38	5.71	5.44	5.98	5.21	5.23	5.31	5.88	4.98	4.83	5.91	6.23	4.078	3.28	2.15
ΣX^2	351.52	393.17	360.19	434.94	338.21	332.28	342.03	417.13	300.25	282.66	421.77	468.54	202.6975	133.8794	63.5216

$(\Sigma X_{Aroma})^2 = 35118.76$

$(\Sigma X_{Flavor})^2 = 35834.49$

$(\Sigma X_{Texture})^2 = 39960.01$

$(\Sigma X_{Moisture})^2 = 47132.41$

$\Sigma X_{Aroma} = 187.4$

$\Sigma X_{Flavor} = 189.3$

$\Sigma X_{Texture} = 199.9$

$\Sigma X_{Moisture} = 217.1$

$\Sigma X_{Aroma}{}^2 = 989.98$

$\Sigma X_{Moisture}{}^2 = 1320.61$

$\Sigma X_{ij(c)} = 114.11$

$\Sigma X_{ij(c)}{}^2 = 400.0985$

$\Sigma(X_{Moisture}\ X_{Aroma}) = 1135.23$

$\Sigma\Sigma X_{ij} = 793.7$

$(\Sigma\Sigma X_{ij})^2 = 629959.69$

$\Sigma X_{ij}{}^2 = 4442.69$

$(\Sigma X_{A(C)})^2 = 2394.1449$

$(\Sigma X_{B(C)})^2 = 1549.2096$

$(\Sigma X_{C(C)})^2 = 666.6724$

$(\Sigma X_{Aroma})\ (\Sigma X_{Moisture}) = 40684.54$

$\Sigma X_{Flavor}{}^2 = 1008.11$

$\Sigma X_{Texture}{}^2 = 1123.99$

$[\Sigma X_{ij(c)}]^2 = 1610.0921$

ANSWER SHEET FOR PARTS I AND II

Directions: Blot out <u>completely</u> the letter corresponding to your answer.

Example: If your choice for the answer to item 1 is "a", you will blot out the "a" completely and the answer sheet will appear as follows:

1. ● b c d e

<u>Part I</u>

1.	a	b	c	d	e
2.	a	b	c	d	e
3.	a	b	c	d	e
4.	a	b	c	d	e
5.	a	b	c	d	e
6.	a	b	c	d	e
7.	a	b	c	d	e
8.	a	b	c	d	e
9.	a	b	c	d	e
10.	a	b	c	d	e
11.	a	b	c	d	e
12.	a	b	c	d	e
13.	a	b	c	d	e
14.	a	b	c	d	e
15.	a	b	c	d	e

<u>Part II</u>

16.	a	b	c	d
17.	a	b	c	d
18.	a	b	c	d
19.	a	b	c	d
20.	a	b	c	d
21.	a	b	c	d
22.	a	b	c	d
23.	a	b	c	d
24.	a	b	c	d
25.	a	b	c	d
26.	a	b	c	d
27.	a	b	c	d
28.	a	b	c	d
29.	a	b	c	d
30.	a	b	c	d
31.	a	b	c	d
32.	a	b	c	d
33.	a	b	c	d
34.	a	b	c	d
35.	a	b	c	d

APPENDIX C

X X X

A STATISTICAL TEST OF THE THEORY THAT PEOPLE ARE AFFECTED BY THE SUBCONSCIOUS IN THEIR CHOICE OF NUMBERS

X X X

conducted
by

WILLIAM F. BOONE

January 1959

instructor:
C. M. Bridges

INTRODUCTION AND STATEMENT OF QUESTION

The theory has been set forth by certain eminent psychologists (see note below) that people, in their choice of numbers from a group presented them, are affected not only by chance, but also by their own subconscious thoughts. It is further stated that, given a particular group of numbers (e.g., the series 1, 2, 3, 4, 5), a subject will tend to shy away from the extremes (in this case, 1 and 5) and will choose an odd number over an even one. If this is true, we should be able to assume that in any normal, unbiased sample, the subjects will show a tendency to choose one and five least frequently, and to choose three most frequently, in the case mentioned above. Therefore, our question is: Does the sample we shall take give us reason to believe that this theory is true or false? More specifically: Does the frequency of the choice of the numbers vary significantly from number to number?

(Note: In spite of considerable research, the original source of this theory has not been determined. However, it is the theory and not the theorist that is of greatest importance. It is thought that the theory is related directly or indirectly to an article published in <u>Scientific American</u> magazine, Vol. 199, No. 3; September, 1958. The article, "The Psychology of Imagination" written by Frank Barron, Research Psychologist at the University of California's Institute of Personality Assessment and Research at Berkley; is concerned with tests of creativeness and independence of judgment carried on at the University of California under the direction of Mr. Barron).

Hypothesis

The choice of numbers is affected only by chance, and being affected only by chance, the proportion of their being chosen is the same.

Ho: $P_1 = P_2 = P_3 = P_4 = P_5 = p$

METHODS AND PROCEDURES

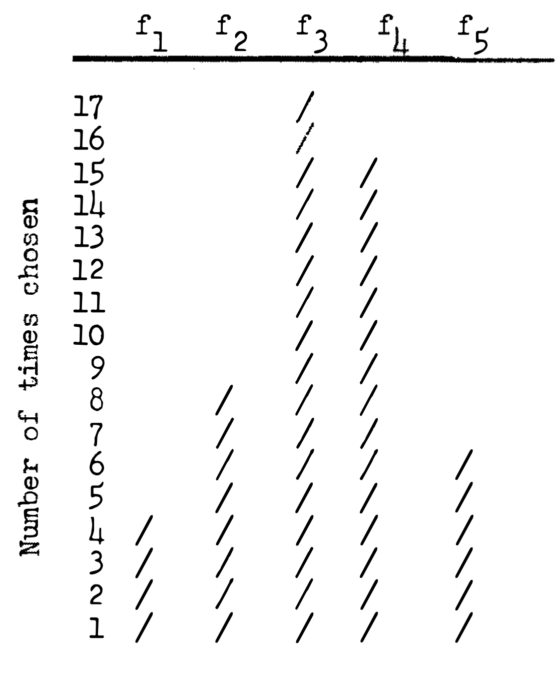
To gather data, a sample of fifty people was taken. Subjects from several different groups were chosen to assure that the data would be unbiased. A white card, such as the one outlined below, with the numbers 1, 2, 3, 4, 5 typewritten on it was presented to each subject. They were asked to "choose a number from this group." This eliminated the use of the word "one" in such an expression as "choose one of these numbers." The choices of the subjects which had previous knowledge of the experiment or were acquainted with the theory under study were removed from the data.

1 2 3 4 5

The method used to test the data under question was the <u>χ^2 test for equality of population proportions</u>. An alpha risk of 5 per cent was used. The data collected and the analysis of the data follows.

PRESENTATION AND DISCUSSION OF DATA

The following data was collected in the manner described in the previous section.



χ^2 TEST FOR EQUALITY OF POPULATION PROPORTIONS

No.	fo	$(f_o - f_e)$	$(fo-fe)^2$
1	4	-6	36
2	8	-2	4
3	17	7	49
4	15	5	25
5	6	-4	16
			$\Sigma = 130$

1. Is it reasonable to suppose that $P_1 \neq P_2 \neq P_3 \neq P_4 \neq P_5 \neq p$

$$f_e = p = \frac{\text{no. in sample}}{\text{no. of categories}} = \frac{50}{5} = 10$$

2. Ho: $P_1 = P_2 = P_3 = P_4 = P_5 = p$

3. $\alpha = 5\%$, test (b).

4. Reject Hypothesis if:

$$\chi^2 > \chi^2\ (.95,\ df = 4)$$
$$\chi^2\ (.95,\ df = 4) = 9.488^*$$

5. Computed χ^2:
$$\chi^2 = \Sigma \frac{(fo - fe)^2}{fe} = 13$$

6. REJECT HYPOTHESIS.

Using the χ^2 test for equality of population proportions, we can assume, at the 5 per cent level, that there is a significant difference in the proportions under study.

SUMMARY AND CONCLUSIONS DRAWN FROM THE DATA

Using the χ^2 test, we have found that, with 95 per cent confidence, we may say that the frequency of the choice of numbers from a group is definitely affected by things other than chance. It is to be noted that at the 99 per cent level our computed χ^2 would become marginal ($\chi^2_{.99, d=4} = 13.277^*$). Therefore we may consider ourselves 99 per cent confident that this is true. It is notable that there is a significant difference between the frequencies of two and four being chosen.

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*Values taken from Standard Mathematical Tables, published by the Chemical Rubber Publishing Company.

This may be due to the very nature of the digits themselves, four being more "complicated" than two. However, in order to prove this, a thorough study would be required.

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* Taken in part from Scientific American, Vol. 199, No. 3, September, 1958.

STATISTICS REPORT

ESTIMATE OF POPULATION

WILLIAM J. ETHERTON, JR.

JANUARY 26, 1959

Index

I. The work here-in is the applied use of a few of the statistical procedures learned in the past semester. It is a statistical estimate of the population of Knox County, one of the counties comprising East Tennessee.

II. The problem was to determine the population of Knox County without making a house to house canvas.

III. The methods used to attack the problem are described in detail. They are:

1. The number of dwelling units in Knox County were obtained.
2. The number of persons per dwelling unit was determined by taking random samples of one hundred houses and computing the average number of occupants per unit.
3. After the mean number of people were computed this number was multiplied by the number of dwelling units as an estimate of the population.

IV. The presentation and discussion of data.

The random samples:

4	5
6	1
2	1
6	6
5	2
5	4
2	1
8	3
4	3
7	1
3	4
7	3
2	5
4	5
2	1
2	3
2	4
5	4
4	2
4	2
3	4
4	3
2	4
3	3
2	4
1	2
2	4
2	5
2	2
5	2
2	3
4	4
3	5
6	5
1	3
2	1
2	3
3	5
5	3
3	2
2	1
4	1
6	4
4	2
1	4
3	3
5	4
3	4
2	3
4	7

These numbers represent 100 randomly selected dwelling units and the number of occupants in each.

IV. The presentation and discussion of data cont.

$EX^2 = 1371$

$(EX)^2 = 112225$

$N = 100$

$EX = 335$

$$s^2 = \frac{1371 - \frac{112225}{100}}{99}$$

$$s^2 = \frac{1371-1122.25}{99}$$

$$s^2 = \frac{248.75}{99}$$

$$s^2 = 2.3105$$

$$s = 1.52$$

$$\bar{X} = 3.35$$

```
   60,056
     3.35
   300280
  186168
 186168
 207,787.6
```

207,787.6 An estimate of Knox pop. with sample of 100.

IV. Cont.

A list of formulae used to arrive at conclusion.

$$s^2 = \frac{\Sigma X^2 - \frac{(\Sigma X)^2}{n}}{n-1}$$

The formulae used to compute the standard deviation.

$$s = \sqrt{\frac{\Sigma X^2 - \frac{(\Sigma X)^2}{n}}{n - 1}}$$

The formulae used to compute the variance.

$$\bar{X} = \frac{\Sigma X}{n}$$

The formulae used to compute the mean.

V. The difference in this data may be attributed to several factors. These are:

1. Size of sample
2. Information is from 1950 census
3. Inaccuracy of calculations

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1. Fundamental Statistics for Business and Economics, Neter and Wasserman, 1954, page 348.

APPENDIX D

Quiz Number One

1. Code the following data and compute the mean, variance, and standard deviation: 99.999, 99.990, 99.997, 99.999, 100.000, 99,997.

2. Each of ten values was reduced by subtracting 0.999 and the resulting differences were each multiplied by 10^3. The sum of the coded values was 6. The sum of the squared deviations from the sample mean was 26.4. What are the mean, variance, and standard deviation for the sample in terms of the original data?

Quiz Number Two

1. A box contains 5 white balls and 4 black balls. If the balls are drawn one at a time from the box without replacement, what is the probability that the balls will alternate in color?

2. If you are to draw 5 balls from the box in problem one, what is the probability that there will be 3 white and 2 black balls in the sample?

3. If you are asked to choose a number between 1 and 15, what is the chance that it is a multiple of 3 or 4?

Quiz Number Three

1. A student taking a true-false test consisting of 10 questions guesses at the answers. Assuming his probability of guessing correctly to be one-half on each question, find the probability that his answers will all be correct.

2. Using the Poisson approximation of the binomial, what is the probability that a student will answer two of the questions correctly?

Quiz Number Four

1. What is the probability that a value of X drawn from an infinite and continuous population having $\mu = 8$ and $\sigma^2 = 4$

   a. will be at least 6? b. will be at most 9?
   c. will be between 7 and 10?

2. A supplier of a type of metallic strip guarantees that not more than thirteen strips in 10,000 will be narrower than one inch with a standard deviation of 0.06 inches. A sample of 49 strips is subjected to measurement and found to have an average width of 1.15 inches. Using a 0.01 level of significance, is the supplier meeting his guarantee? Set up the 98 per cent confidence interval estimate of the true mean. What size sample would be necessary if it is desired with 98 per cent confidence that the sample mean be at most 0.002 inches from the true mean?

Quiz Number Five

1. It has been asserted by some that the true proportion of people of race X having blood type O is 0.50. A person types 1000 people of this race and finds that 540 have type O blood. At the 5 per cent level of significance, is the assertion compatible with this data?

2. Over a given test run, 6 cars of a particular make and model had an average gas mileage of 12 miles/gallon, with a standard deviation of 2.12 miles/gallon. At the 1 per cent level of significance on a symmetrical test, is this consistent with advertising claims that the average gas mileage for this model and make of car is 14 miles/gallon? Set up the 95 per cent confidence interval estimate of the true mean gas mileage for the cars.

Quiz Number Six

1. In a diet experiment using a certain type of animal, eleven animals were given Diet A and eleven were given Diet B. Those fed Diet A gained 13.5 ounces on the average with a standard deviation of 4 ounces while the average weight gain for the animals receiving Diet B was 11 ounces with a variance of 5 ounces^2. Is it likely at the 1 per cent level of significance that the diet has a real effect on weight gain? Assume a common variance.

2. At the 5 per cent level of significance could you say that the true variance of those animals fed Diet A was 4.5 ounces?

Quiz Number Seven

1. Two groups of people (I and II) were interviewed with respect to a certain problem. The following table gives the results of the poll.

	No	Yes	Total
Group I	50	50	100
Group II	70	130	200
Total	120	180	300

Are the two classifications independent at the 5 per cent level of significance?

2. From a 6 x 3 contingency table a χ^2 value of 9.30 was computed and the experimenter concluded that the result was significant. Do you agree?

Quiz Number Eight

1. In tossing pennies 32 times the following results were obtained:

No. Heads	Frequency
0	2
1	10
2	10
3	4
4	6

Do these results differ significantly from those expected on the basis of randomness in the tossing?

2. From a sample of 17 observations with a mean of 30 and standard deviation of 2, compute the 90 per cent confidence interval estimate for the true population variance.

Quiz Number Nine

A company wishes to know whether practice in a certain sorting operation increases the quality of performance. Three groups of operators each are tested. Each group performed the operation for 34 minutes. The rest intervals between trials were 8, 2, and 0 minutes for Groups A, B, and C, respectively, and the numbers of trials for each group in the same order were 5, 11, and 29. Numbers of correct classifications for each operator upon test follows:

A	B	C
52	51	54
55	52	53
53	51	52

Code your data around 52. Is there any evidence at the 5 per cent level of significance that the amount of practice in this operation has a real effect on performance quality?

Quiz Number Ten

In testing filter cigarettes for nicotine (X) and tars (Y), the following values were obtained for 10 cigarettes: $\Sigma X = 17.6$, $\Sigma X^2 = 33.46$, $\Sigma Y = 200.6$, $\Sigma Y^2 = 4169.86$, $\Sigma XY = 363.50$. Does a significant relationship exist between the two factors? What tar level would you estimate from a nicotine level of 1.6?

APPENDIX E

First Hour Examination

1. The following sample values have been coded by subtracting 0.91356 from each and then multiplying the difference by 10^5. Compute the mean, variance, and standard deviation for these values: 2, -4, 6, 3, -5, -9, 7, 8, 6, 9.

2. In a class of 12 students, five are boys and the remainder girls. If two students are selected to represent the class on Honors Day, what are the odds against their both being girls?

3. In a class election there are two parties. John is nominated by one party and the probability that he will be elected is 3/4 provided William is not nominated by the opposition. The probability that William will be nominated is 1/3 and the probability that he will be elected if nominated is 2/3. What is the probability that John will be elected?

4. Drawings are made by simple random selection without replacement from an ordinary deck of playing cards. In 10 drawings, what is the probability of drawing at most 9 red cards?

Second Hour Examination

1. An experiment is performed as follows: A cuts a well-shuffled deck of playing cards and observes the color of the cut card. As A cuts the deck each time B tried to read his mind and writes down red or black. If B has no talent and is guessing, what is the probability that in 10 such trials he will call 8 correctly?

2. Work this same problem by use of the Poisson approximation to the binomial.

3. A shipment of electrical switches is packed in boxes of 100 each. A box is inspected by examining 20 switches and rejecting the box if any of the 20 are defective. What is the probability of rejecting a box containing 3 defectives if there are 8 defectives in the lot? The switches are tested one at a time.

4. If you have two nickles and two dimes in each pocket, what is the probability that:

    a. drawing one coin at random, it will be a dime?
    b. after selecting a pocket at random, two coins drawn at random will not be alike?

5. Given a normal universe with $\mu = 0.25$, $\sigma^2 = 0.0049$. If a single value of X is drawn at random, what is the chance that:

a. it will differ from the mean by at least 0.10?
b. it will lie within 0.12 units of the mean?
c. the mean of a sample of size 25 will lie 0.0273 units or more above the mean?

Third Hour Examination

1. It is believed that the average cigarette consumption of the American public is eight cigarettes per individual with a standard deviation of four. A sample of 100 individuals was taken and the average cigarette consumption was found to be seven per person. What would you conclude about the basic assumption with respect to the average cigarette consumption?

2. Compute the 99 per cent confidence interval estimate of the true mean for the above problem.

3. What size sample would be required if the obtained sample mean is to be at most 0.5 units from the true mean for this problem?

4. A commercial producer of alcohol runs tests on ten two-ounce specimens of his product to determine the concentration. He knows from past experience that his process has a variance of 36 per cent. As a result of his test, the average concentration is found to be 90 per cent. Is this average consistent with minimum government specifications of 94 per cent concentration?

5. A z-score of 0 on a test would indicate what in describing a student's placement with respect to the rest of the class on a given examination?

Fourth Hour Examination

1. The drained weights in ounces of a random sample of 12 cans of a type of fruit are:

   12.1, 11.9, 12.4, 12.3, 11.9, 12.1, 12.4, 12.1, 11.9, 12.4, 12.3, 12.0.

   Assuming that this sample is representative of the production process, would you say that the advertised minimum average weight was 12 ounces? Use the 1 per cent level of significance for your test.

2. Suppose in reality the sample mentioned in problem 1 was drawn from a population with a true mean of 11.5 ounces instead of the hypothesized 12 ounces. Assume that the population standard deviation is 0.224. Under the three types of tests, what would be the probabilities of committing the Type II error?

3. What size sample would be appropriate for this canning operation test if it was desired that the probability of rejecting the hypothesis be just 0.90 if it is false and the probability of accepting the true hypothesis to be just 0.95 while discriminating between the hypothesized mean and any alternate mean at least 0.5 ounces different?

4. a. Experience shows that 20 per cent of a certain kind of seed germinate. Would you have reason to complain if only twenty-five seeds out of a packet of 200 germinate?

   b. Compute the 99 per cent confidence interval estimate of the true population proportion for the sample given in 4-a.

5. In an experiment to determine the effect of a certain chemical on a type of nerve cell, nine experimental animals were used and nine control animals were used. Before proceeding with the experiment it was desired to know whether or not the location of the cell bodies in the spinal cord would affect the concentration of the test chemical. The control animals were sacrificed and the amount of the test chemical measured in samples taken from each half of the spinal cord for each animal. On the average the samples indicated that the right half contained 1.13 milligrams less than the left half with a standard deviation of 3.14. Is it a fair statement to say that the average difference in the chemical content between the left and right halves in the control animals is zero?