SESSION IV CONTRIBUTED PAPERS: INSTRUCTIONAL APPLICATIONS

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Computer aids in teaching statistics and methodology

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Detailed information is provided on the use of a computer as an aid in the teaching of statistics. A review of the state of the art is included.

The purpose of this paper is to provide teachers of statistics a broad view of the alternative uses of the computer along with as much detailed, explicit information on "how-to" and "where-to-find" as we have been able to muster. We believe that we have comprehensively described the state of the art in the field, although the scattered and fragmentary methods of publication preclude our reporting everything that is being done today. While our principal emphasis will be on the introductory noncalculus course, most of the computer methods described are at least equally useful in higher level courses in statistics and research methodology. In fact, new approaches to the teaching of research skills to social science students tend to blur the distinctions between the introductory statistics course and methods or even content courses.

The use of computers in statistics instruction takes a number of different forms; many courses are taught with a combination of approaches. For convenience, we have formed the initial presentation around the following categories: (a) the use of relatively large statistical packages; (b) the training of students to write their own programs, usually to compute some standard statistical measures; (c) the use of one of

several "high-level" statistical languages; (d) the use of the computer to simulate experimental data for student analysis on or off the computer; and (e) the use of computer-assisted or computer-managed procedures.

The first major section of this paper is devoted to a discussion of the above five major educational strategies. A sixth approach, the use of computer demonstration exercises, is illustrated in some detail in the final section of this paper.

STATISTICAL PACKAGES

The use of large statistical packages such as SPSS (Statistical Package for the Social Sciences; Nie, Bent, & Hull, 1970)¹ or BMD (Dixon, 1968), is relatively rare in statistics courses per se, particularly at the introductory level. However, they deserve mention here because their impact on the teaching of statistics, both direct and indirect, has been enormous.

The computer's promise of freeing the social science researcher from tedious data manipulation and hand calculation of statistics has undoubtedly been fulfilled. Many social scientists and students have been able to employ SPSS and similar packages for these purposes. A recent survey by Anderson² shows that about three-fourths of American graduate schools in sociology have access to large computers such as the IBM 360/65-70 series and the CDC 6000

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series. Not coincidentally, about the same number make some use of SPSS. This widespread usage is remarkable in view of the fact that the package is only about 4 years old. Clearly, SPSS has filled a vital need in social science computing, since its growth has followed fast on the heels of the growth in purchases of large-scale computers by American colleges and universities in the late 60s and early 70s.

Since SPSS was designed as a research tool, its classroom usage has been limited primarily to upper level statistics and methodology courses. The greatest impact of SPSS on the teaching of statistics has been indirect. Its contribution to the ease of doing statistical computation, along with the development of computer techniques generally, has resulted in decreased emphasis on computational techniques in statistics courses. Consequently, more classroom time is available for greater emphasis on the relationship between statistical understanding and the interpretation of results.

Furthermore, we can expect to see more of SPSS and similar packages in lower level courses, although these courses may not be labeled statistics. A "filtering-down" process seems to be taking place, causing advanced research methodology to be introduced at earlier and earlier stages in the curriculum.

A possible assumption underlying this movement is that if students learn methodology at an early stage, they will have a better grasp of what social science is "really" about, develop a healthy skepticism about "received doctrine" in their field, and will be motivated by the "discovery method" inherent in this approach. Examples of this approach are IMPRESS (Meyers, 1969), a statistical package cum data base used for teaching sociology and political science at Dartmouth and a new system at Notre Dame for the teaching of introductory economics (Jameson, Bonello, & Davisson, 1974). These courses blend the teaching of statistical principles, research methodology, and subject matter content in a way that defies classification in the traditional curriculum. At present, they seem to be offered as an alternative to the traditional introductory course in sociology, political science, or economics, but we can expect to see descriptions of similar courses being offered as an alternative to the traditional introductory statistics course in the near future.

Since SPSS is quite large (requiring 200,000 words of memory in its full version), it cannot be implemented on small or medium sized computers. Even at institutions with large computers, it may be considered too expensive for student use because it takes so much core storage and is rather slow. Various smaller packages have appeared which perform many of the functions of SPSS and run on smaller machines. One such program is XTAB9,³ developed at Brown University by James Sakoda. XTAB9 computes crosstabulation, chi square, percentages,

means, and standard deviations, one-way analysis of variance, and correlation coefficients. With extensive overlays, XTAB9 can fit into less than 20,000 words of storage, and can thus run on small computers or take a smaller partition on large ones.

Even if one of the large statistical packages like SPSS or BMD is not available, nearly every college or university computing center has a set of commonly used, and perhaps locally developed, statistical programs. Sometimes the documentation for such programs can be obtained in sufficient quantity to use as class handouts, and the instructor can build problem sets around the existing programs. But, unfortunately, the documentation is often either nonexistent or inadequate. In such a case, the instructor who wishes to use local programs must either attempt (often with little success) to pressure his center into developing such documentation, or write his own, if he can figure out what the program is doing. (More often than not, if an instructor does develop the documentation for class use, he will soon discover that it makes its way to the computer center to be issued as *the* documentation for the program!)

The building of a course around major computational packages represents one of two general philosophical approaches to the use of computers. Typically, such a course uses the computer to completely remove arithmetic computations from the students, concentrating instruction instead upon research logic and the mechanics of computer use. The other general approach, which the authors favor but will not argue in this forum, uses the computer as an adjunct in a more traditional course. This approach, which is represented by the remainder of the techniques discussed in this paper, typically has the students do some arithmetic themselves, or requires that they write their own programs.

There is no reason, of course, why the approaches cannot be combined in the same course. Initially, the students could be required to do hand computation, then write their own program, and finally use canned packages, perhaps on data provided by a data generation program as discussed below.

STUDENT PROGRAMMING APPROACHES

Another approach to the teaching of undergraduate statistics has been the development of courses which emphasize computer algorithms as a means of teaching statistical concepts. The method is to require students to write their own short programs to compute standard statistical measures. The assumption motivating this approach is that if students actually write programs to compute various statistics, they will develop a deeper understanding of the meaning of those measures and will be more sophisticated in their use of canned statistical packages later on.

The first introduction to the computer using this approach will most likely be the execution of a simple

program that requires the student to do only the minimum of work—merely logging onto the computer, perhaps supplying some simple information such as five numbers or his name, and logging off.

If the students are to learn programming or are relative novices, the next step will probably be to either modify an existing program or write a simple "original" program. A good problem is finding the mean of N numbers for this assignment; the students already know the procedure and can follow the computer analog with little difficulty. The standard measures of central tendency (mean, median, mode) provide a graded series of exercises calling for progressively greater programming skills (see Starr, 1972).

Random Numbers

It is a good idea to introduce pseudorandom number generation early in the statistics course since the data used in the mean and later assignments are usually generated by the computer. If the students are writing programs or learning programming along with statistics, they must be given an introduction to random numbers early.

Many of the common programming languages provide easy access to a function which yields a pseudorandom number from a rectangular distribution. In an interactive environment, two of the most widely used languages, BASIC and APL, have rectangular random number functions as a part of their standard repertoire. In facilities where batch processing is the mode, often a function will have been developed which is callable from a standard language such as Fortran or PL/I. If a random number generator function is not available, several sources give appropriate algorithms (e.g., Bulgren, 1971; Lehman & Bailey, 1968; Lohnes & Cooley, 1968). Moreover, the output from rectangular pseudorandom generators may be modified algorithmically to simulate sampling from a variety of other distribution forms. Thus, Hemmerle (1967) provides the logic for generating numbers that behave as if they were drawn from normal, skewed, and Poisson-type distributions. Lehman and Bailey (1968) present methods for simulating normal, geometric, binomial, and bivariate normal distributions.

Random Variables and Distributions

For courses in which there is heavy emphasis upon probability theory and probability distributions, the computer offers an invaluable resource for the student. With a facility for random number generation available, students can write and/or run programs dealing with assignments such as relative frequency as an analog to probability, sampling from binomial, uniform, Poisson, and hypergeometric distributions, and empirically demonstrating the central limit theorem. Bulgren (1971), Carnahan,

Luther, and Wilkes (1969), and Lehman and Bailey (1968) offer a number of appropriate exercises and algorithms.

An interesting technique for students in a first-semester course is to explore the central limit theorem. Students are asked to write a program that makes repeated samples of size N from a uniform distribution 1, 2, ..., K , find the mean of each sample, and tally that mean into a frequency distribution (usually making use of a previously written frequency distribution program). The program also computes the mean and standard deviation of the frequency distribution. The process is repeated for various numbers of means and values of N and K . The effects of sampling from distributions other than the rectangular can also be studied. The results often seem to be a better understanding of central limit theorem and the relationships among sample size, the shape of the sampling distribution, and the size of the standard error.

Hypothesis Testing

Students may be required to either write and run or merely run a variety of programs dealing with various hypothesis testing procedures. An interesting kind of exercise involves sampling repeatedly from some normal population, finding the mean of each sample, and determining whether that obtained mean lies outside the critical limits for some statistical test such as Z or Student's t . A frequency distribution of the obtained values of the statistic may be constructed, and a tally of the proportion of "rejections" of the null hypothesis will illustrate the concept of Type I error.

Both Bulgren (1971) and Lohnes and Cooley (1968) offer a selection of exercises for the student in Monte Carlo studies of hypothesis testing procedures as described above.

Many statistics teachers will object that student programming in the teaching of statistics is an unnecessary (even irrelevant) intrusion into an already crowded course. Still, the fact remains that in recent years an increasing number of instructors have decided that the benefits of programming outweigh the losses. Some institutions require a programming course early in the social science curriculum. In such cases, it seems reasonable to combine the teaching of programming techniques with applications in the introductory statistics course.

STATISTICAL LANGUAGES

An approach which stands midway between the use of large statistical packages and the student programming approach is the use of OMNITAB (Swanson, Ledlow, & Harris, 1973), MINITAB (Ryan & Joiner, 1973),⁴ OMNISHRIMP (Harris, Swanson, & Duerr, 1974), or SMIS/SIS (Castellan, 1970). These are statistically oriented computing systems somewhat similar to SPSS but permitting

greater flexibility in their use and hence requiring somewhat greater statistical expertise and initiative on the part of the user. Because their control cards resemble high-level computer instructions (e.g., "ORDER THE DATA IN COLUMN 2"), their authors sometimes refer to them as languages. These systems offer the promise of providing almost as much ease in computing as SPSS-like packages, while retaining an algorithmic control structure which should tend to maintain a greater awareness of the underlying computational procedures on the part of student users.

Like SPSS, OMNITAB requires a large computer and is considered rather slow, and hence expensive, for student use. However, MINITAB and OMNISHRIMP are smaller, faster systems which run on medium sized computers. We expect their use in statistics instruction to grow as they become more widely disseminated.

A similar "high-level language" approach is that represented by SMIS/SIS (Castellan, 1970). This Fortran system operates upon a user-input data matrix, and provides 48 matrix manipulation operations and 25 statistical procedures. The system also provides access to user-written subroutines, making it locally modifiable. Castellan (1974) reports on the use of SMIS/SIS in both the type of undergraduate course being discussed here, and in a graduate multivariate analysis course.

SIMULATING EXPERIMENTAL DATA

Another important computerized aid in teaching statistics need not involve the students with the computer in any direct way, but uses the computer as a fancy random number generator.

In this application, the computer not only eliminates the tedium of statistical computation, but also eliminates the collection, input, storage, and manipulation of data from real experiments. It is particularly well suited to psychology, but applications exist in other fields as well.

A perennial problem to statistics instructors is the development of new sets of data to be used on problem sets and examinations, as class examples, and so forth. To make matters worse, whenever new data or problems are introduced, the instructor (or his assistant) must compute a new answer key. Another problem arises from the "sharing" of results of assignments across semesters, sections, and/or students. The use of computer-generated data with known solutions printed by the computer can greatly alleviate all of these problems.

Lehman has developed and used a set of data generator programs with a great deal of success in several courses. These programs include generators for single-variable independent-groups designs, generalized analysis of variance designs, and for both bivariate and multivariate experiments. The

programs are written in Fortran, and are available to anyone who is interested (see Lehman, 1973).

One technique in using data generators is to provide unique sets of data for each student on a problem set or examination. Since the generators produce an "instructor's record" containing both the parameters of the population(s) sampled and the statistics for the particular sample obtained, grading the student's work is simplified. If the same population parameters are given for all sets of data for a given problem on a problem set, and if a little care is given to picking the parameter values, it is interesting to construct the class-wide frequency distribution of obtained results which can illustrate Type I errors in a particularly meaningful way. In addition, since parameters are known, a wide variety of other important effects can be illustrated, including the effects of sample size, alpha level, or the magnitude of the "true" difference on power and Type II errors.

Another advantage to generating data from known populations is the development of an individualized approach to an advanced course. A course where students design hypothetical individual experiments, receive individual data, and conduct individual analyses has been described elsewhere (Lehman, Note 1).

On a slightly grander scale, Suziedelis (Note 2) and Harper (1972) have developed complete data bases with known parameters for teaching quantitative procedures in social psychology and sociology, along with appropriate analytic systems to allow students to formulate and test meaningful hypotheses.

Another approach to data generation is represented by the highly developed EXPER SIM system from Michigan (Main, Note 3; Rajeci, Note 4). EXPER SIM, also known as the Michigan Experimental Simulation Supervisor (or MESS), is a set of sophisticated computer simulation models for various experimental situations in specific substantive areas. The system presently includes simulations for imprinting, social facilitation, drug research, etiology of schizophrenia, and motivation. Each simulation includes a complete specification of the experimental setting, descriptions of built-in controls, and a number of variables (typically 6 to 10) that can be manipulated. EXPER SIM takes the variable settings that are given and generates sets of data, along with appropriate statistics if requested. The student may then analyze the data, just as if it were a real experiment. This is often followed by another "experiment," and so forth.

EXPER SIM has several features that are of interest to the instructor of statistics and experimental design. In the first place, the data are realistic, in the sense that the effects of the variables that can be manipulated are similar to the effects that those same variables have in the "real world." Secondly, the

system is very easy to use, and it is very tolerant of errors in input (even down to the level of misspellings and incorrect punctuation).

Third, the entire system is conceived as a subtle introduction to computer modeling; students are presented with a model of a behavioral domain and are to infer the underlying structure.

MESS is readily expandable so that new simulations can be added as only a single Fortran subroutine and perhaps a data file which gives certain constants and default values. Currently under development is a simulation writer program (SWIP) that will automatically produce the correct subroutine, thus making the introduction of new models a relatively simple matter for the instructor.

EXPER SIM has been exported to a number of other installations. It is now being given support through the Exxon Education Foundation, which is offering grants to institutions desiring to implement the system.⁵

COMPUTER-ASSISTED AND COMPUTER-AUGMENTED INSTRUCTION

Although CAI (Computer Assisted Instruction) has been highly touted by the mass media, its use in higher education has been limited. CAI refers to the use of the computer as a tutor, largely independent of human instructors. The assumption underlying CAI development efforts is that students can master complex material better and faster if it is presented to them in easy stages with frequent quizzes and immediate feedback to student responses.

However, CAI has inherently high development and operating costs. The authors know of no general CAI programs for college-level introductory statistics that are applicable on systems other than where they have been developed. There have undoubtedly been some courses developed, perhaps at Illinois with the PLATO system. An interactive tutorial system, the Statistical Help and Instructional Program (SHIP) is in operation at the University of Colorado's Computer Laboratory for Instruction in Psychological Research (CLIPR), but it is doubtful that it can be exported to any other installation.

Since the publication of Keller's paper on self-paced instruction (Keller, 1968), the "Keller method" has been introduced into a number of courses throughout the country. Somewhat surprisingly, very few reports have been made regarding the use of the Keller method in statistics and experimental design courses.

One commercial publisher has developed an individualized set of materials for the first-semester statistics course (Individual Learning Systems, 1971). The authors know of two other related efforts, both of which use the computer.

Kotesky (1972) has developed and published a set of computer programs for generating multiple

alternate forms for statistics tests, an essential element in a self-paced program. For the preparation of more traditional problem sets, but with unique sets of data and solutions, Tracy and Salmon (1974) offer a set of Fortran programs for generating exercises. Both of these two sets of programs are available through Life Science Associates.

DEMONSTRATION PROGRAMS AND LABORATORY EXERCISES

Although some of the earliest applications of the computer to the teaching of statistics consisted of demonstration programs and laboratory exercises, and although development of this type of material is in progress on many campuses, no one has succeeded in developing and disseminating a standard package of programs for this purpose. This lack is partly due to idiosyncratic differences in teaching which would require that such a package have a great many variations (or serve a very narrow market); it is partly due to technical problems of transportability; and it is partly due to the fact that developments in computer technology, particularly the rapid growth in timesharing, have tended to render obsolete the early programs. Until quite recently, most programs of this type were written in batch mode and student usage consisted of an examination of sample printouts.

Conversational timesharing programs have a distinct advantage in this type of use, since they permit student initiative in setting parameters and hence choosing variations in the demonstrations as they run. Other innovations have increased the availability of computers for in-class demonstrations and experiments. Minicomputers, phone lines into the classroom coupled with TV monitors, and kinescope projectors all provide an increasing number of instructors with the option of using the computer in class as a supplement to the lecture. For some demonstrations, these devices may provide a medium that is superior to either batch-mode printouts or individual laboratory exercises.

In this section, we will discuss seven topics that are commonly suggested for the introductory statistics course (see Committee on the Undergraduate Program in Mathematics, 1972). For each topic, we will either illustrate one possibility for computer enhancement in the form of demonstration or exercise or suggest how the computer might be used.

Statistical Description

A useful technique in developing skill and understanding in descriptive statistics is to have students work in parallel with the computer. A program may be provided for the students that will construct a frequency distribution and compute the mean, variance, and standard deviation of a set of input data. If the computer and the student are given the same data, several interesting possibilities result.

The program might, for example, compute the statistics using both raw-score and grouped-data techniques, thus allowing the student to see the possible biasing effects that grouping may have. If the program is provided with a variable interval size, the same data may be run with differing interval sizes, allowing experimentation with the effects of that variable on the shape of the obtained distributions and on the values of the statistics.

This step can be combined with the introduction to the computer, so that the first or second program that the student must use computes a frequency distribution. The accompanying assignment can require that one or two distributions be constructed by hand, and those plus several others be done by the computer.

Most computer center libraries contain descriptive statistics programs that can be used. However, Appendix A describes a BASIC program that was written especially for student use at this point in the course, and that is available to interested readers.

Probability, Random Variables, and Distributions

A variety of programs might be employed to aid in the teaching of these topics. For example, Appendix B describes a simple program to check on the efficacy of a rectangular pseudorandom number generator. A series of numbers between 1 and 10 are generated. The program then calculates the frequency, sample probability, and cumulative probability of each number's occurrence. Theoretically, of course, each number should be equally probable, but deviations from expectations are illustrative.

A program could also be used to drive home the notion of statistical independence. To take a simple example, an instructor might specify a two-way table showing the relationship between, say, obesity and sex. The computer could be used to generate the probability of being male in the population, of being nonobese, and one single-cell probability such as obese and female. The student could then be required to supply all remaining probabilities until he or she abstracts the principle that only when the products or the marginals exactly equal the cell probabilities for all cells is there true independence.

Bulgren (1971) and Lohnes and Cooley (1968) offer a large number of exercises that could inspire an interested instructor.

Special Probability Distributions

Programs to simulate coin tossing or dice throwing are useful for introducing the binomial distribution. One such program is DICE, described in Appendix C. DICE not only demonstrates the binomial distribution but helps introduce the notion of sums of random variables and the difference between expected values and observed sample values of a distribution. More sophisticated programs and

problems are available. Snell (1971) has described a series of more complex projects used in the probability theory course taught jointly by Snell and John Kemeny at Dartmouth.

Sampling Distributions

An earlier section of this paper described how, in a course requiring student programming, students may be assigned a program to illustrate the central limit theorem.

For courses that do not require student programming, the instructor can write such a demonstration or use a canned one. It is particularly helpful if the program contains graphical output to illustrate the process of convergence. This type of program is especially well suited for an in-class demonstration if facilities permit.

For the reader who does not wish to write his own, Appendix D contains a description of MONTE, a conversational central limit theorem demonstration program written in BASIC, available to interested readers.

Inferences Concerning Population Means

One of the more difficult concepts in the beginning statistics course is that of the power of a test. One good approach is to provide a program that computes the power function for a single-sample study, given a null hypothesis value, population variance, sample size, and significance level. The students are expected to run the program several times, using different values for some of the possible variables and plot the resultant power curves. The educational result should be an understanding of the impact of significance level and sample size on power that rests more on the students' experience and less on "faith" (as is often the case in courses employing only lecture and text).

A description and sample output of such a program may be found in Appendix E.

Chi Square and Contingency Tables

One of the interesting properties of the chi-square statistic is that its value is directly proportional to the size of the sample, assuming constancy of the relative sizes of the cells in a contingency table. This can be readily demonstrated by adapting a chi-square computation program to allow the user to multiply the numbers in each cell of the contingency table by a user-supplied factor.

Correlation and Regression

A good bivariate scatterplot program is a valuable aid in presenting correlation and regression. Most computer centers can supply one, although often it must be adapted. One possible exercise might be to have students prepare the plot of a set of data, and compute both the correlation coefficient and the values for regression. Then the same data are submitted to the program as a check.

A more sophisticated approach would be to develop a program which embodies a bivariate normal data generator, allowing the student to specify the population parameters and correlation. If the program then conducted a "standard" scatter plot and correlation analysis, several runs could allow a number of population correlation values to be compared. An even more advanced version of the same program could allow for truncation of the range of one or both variables by simply discarding any generated values which fall outside the allowable range.

CONCLUSION

At first, the computer was used by psychologists only as a data processing tool for research. While that role of the computer is valuable and has certainly led to an advancement in the sophistication of research technique, only in recent years has it had any significant impact on the process of teaching. We have here focused on the computer as an adjunct in the process of teaching statistics. The developments reported have not been in the use of CAI, but in allowing the power of the computer to expand the kinds of examples and exercises that are available for the instructor and student. We expect that these uses of the computer will continue to grow and develop as more instructors become aware of what the computer can do for them and their students.

We hope that this presentation of the current status of instructional computing in statistics will prove helpful. The authors will be pleased to hear from anyone who adapts some of these suggestions into his own teaching, or who has additional ideas to share.

APPENDIX A

Descriptive title. Multi-Purpose Descriptive Statistics Program.
Program name. ANALYZ.

Author. David P. Doane, Oakland University (Michigan).

Summary of content. Given N pieces of sample data, this program computes 17 measures of central tendency, dispersion, and skewness. In addition, it has options for ordering and standardizing the data and/or grouping the data and constructing a histogram.

Educational objectives. This program is designed as an introduction to descriptive statistics, including frequency distributions.

Specification of the computer's educational role. The program is designed to be used by students in connection with a laboratory assignment on descriptive statistics.

Technical comments. The program was written in BASIC and run on a Burroughs 5500. It requires no programming on the part of faculty or students.

Availability. For a listing and/or paper tape of this program, write: David P. Doane, Oakland University, Rochester, Michigan 48063.

APPENDIX B

Descriptive title. Frequency and Probability Calculation Program.

Program name. RPROB.

Author. B. James Starr, Howard University.

Summary of content. Generates a specifiable number of random numbers between 1 and 10, and calculates the frequency of occurrence, simple probability, and cumulative probability of the possible values.

Educational objectives. The program is designed as a basic introduction to the frequency notion of probability and as a check on the rectangularity of a random number generator.

Specification of the computer's role. The computer samples and tallies with a speed that makes this kind of exercise possible—it's not by hand!

Technical comments. BASIC for a CDC 6400.

Illustrative output:

HOW MANY RANDOM NOS. WOULD YOU LIKE TO SAMPLE ? 100

RAND. NOS. EQUAL TO...	FREQUENCY	PROBABILITY	CUM. PROBABILITY
1	10	.1	.1
2	9	.09	.19
3	9	.09	.28
4	10	.1	.38
5	11	.11	.49
6	12	.12	.61
7	8	.08	.69
8	8	.08	.77
9	11	.11	.88
10	12	.12	1

RUN COMPLETE

PROVIDE A 6-DIGIT NO. TO START THE RANDOM NO. GENERATOR ? 443865
HOW MANY RANDOM NOS. WOULD YOU LIKE TO SAMPLE ? 1112

RAND. NOS. EQUAL TO...	FREQUENCY	PROBABILITY	CUM. PROBABILITY
1	118	.106115	.106115
2	100	8.99281E-2	.196403
3	107	.096223	.292266
4	108	9.71223E-2	.389388
5	131	.117806	.507194
6	117	.105216	.61241
7	109	9.80216E-2	.710432
8	94	8.45324E-2	.794964
9	122	.109712	.904676
10	106	9.53237E-2	1

STOP

Availability. For a listing, contact: B. James Starr, Department of Psychology, Howard University, Washington, D.C. 20001.

APPENDIX C

Descriptive title. Simulation of Dice Throwing.

Program name. DICE.

Authors. Kenneth C. Young, Eastern Michigan University; David P. Doane, Oakland University (Michigan); Harvey Shapiro, Oakland University (Michigan).

Modified by. David P. Doane.

Summary of content. Basic notions of combinatorial probability can be illustrated by gaming devices such as dice. In addition, sums of random variables and the binomial distribution are well illustrated by the roll of two or three dice. The DICE program enables the user to simulate the roll of one, two, or three dice. It summarizes the outcomes in a histogram and prints expected as well as actual outcomes of each simulated experiment. The program also produces a table of exact binomial probabilities for any given number of trials and probability of success. Finally, it provides the option of making the simulated dice rolls into a game which focuses attention on the difference between the expected frequency of outcomes and the actual outcomes.

Educational objectives. The purpose of the program is to provide a technique to assist students in gaining an intuitive understanding of combinatorial probabilities, sums of random variables, and the binomial distribution.

Specification of the computer's role. The program can be used as a classroom demonstration or as a laboratory exercise for students.

Technical comments. The program was written in timesharing BASIC for a Burroughs 5500. It has 273 statements. It is conversational in nature and all data input is via Teletype under program control. No programming is required on the part of instructor or students.

Illustrative output:

```
DO YOU WANT INSTRUCTIONS (Y OR N) ?Y
WELCOME. IN THIS RANDOM EXPERIMENT I WILL SIMULATE THE
ROLLING OF 1,2, OR 3 DICE. YOU WILL TELL ME HOW MANY
TIMES TO ROLL. THEN I WILL PRINT A HISTOGRAM OF THE OUT-
COMES. I WILL ALSO SHOW VALUES FOR F(O) AND F(E), WHERE

F(O) IS THE ACTUAL FREQUENCY OF OUTCOMES OF EACH TYPE
F(E) IS THE EXPECTED (BINOMIAL) FREQUENCY OF OUTCOMES

IF YOU WISH, THE DICE ROLLS CAN BE MADE INTO A GAME. SHALL I
EXPLAIN THE GAME (Y OR N) ?N
DO YOU WANT A GAME (1) OR A REGULAR SIMULATION (2) ??
ENTER A 2-DIGIT NUMBER TO START ?23
HOW MANY DICE DO YOU WANT ME TO THROW (1,2, OR 3;0=STOP) ?1
HOW MANY TIMES DO YOU WANT ME TO THROW ?12
DO YOU WANT TO SEE EACH THROW ?N
```

OUTCOMES FOR ONE DIE

#	EXPTD F(E)	ACTUAL F(O)	HISTOGRAM
1	2	1	*
2	2	3	***
3	2	1	*
4	2	4	****
5	2	1	*
6	2	2	**

```
HOW MANY DICE DO YOU WANT ME TO THROW (1,2, OR 3;0=STOP) ??
HOW MANY TIMES DO YOU WANT ME TO THROW ?22
```

OUTCOMES FOR TWO DICE

#	EXPTD F(E)	ACTUAL F(O)	HISTOGRAM
2	2	3	***
3	4	6	*****
4	6	7	*****
5	8	8	*****
6	10	8	*****
7	12	9	*****
8	10	9	*****
9	8	7	*****
10	6	11	*****
11	4	2	**
12	2	2	**

```
HOW MANY DICE DO YOU WANT ME TO THROW (1,2, OR 3;0=STOP) ?3
```

```
HOW MANY TIMES DO YOU WANT ME TO THROW ?216
```

OUTCOMES FOR THREE DICE

#	EXPTD F(E)	ACTUAL F(O)	HISTOGRAM
3	1	1	*
4	3	1	*
5	6	5	*****
6	10	11	*****
7	15	17	*****
8	21	25	*****
9	25	27	*****
10	27	23	*****
11	27	28	*****
12	25	20	*****
13	21	25	*****
14	15	16	*****
15	10	5	*****
16	6	9	*****
17	3	2	**
18	1	1	*

```
HOW MANY DICE DO YOU WANT ME TO THROW (1,2, OR 3;0=STOP) ?0
DO YOU WANT A TABLE OF EXACT BINOMIAL PROBABILITIES ?Y
HOW MANY TRIALS (N) ?12
WHAT IS THE PROBABILITY OF A SUCCESS (P) ?.1666
DO YOU WANT A COMPLETE TABLE (FROM 0 TO 12) ?Y
```

BINOMIAL TABLE: R IS THE NUMBER OF SUCCESSES

R	P(X=R)
0	0.1123
1	0.2693
2	0.2961
3	0.1973
4	0.0887
5	0.0284
6	0.0066
7	0.0011
8	0.0001

PROBABILITIES LESS THAN .0001 HAVE BEEN OMITTED.

```
DO YOU WANT A TABLE OF EXACT BINOMIAL PROBABILITIES ?N
STOP
```

Availability. For further information concerning this program, availability of tapes, and an extensive student guide to the use of this and other statistics programs, write: David P. Doane, School of Economics and Management, Oakland University, Rochester, Michigan 48063.

APPENDIX D

Descriptive title. Central Limit Theorem Demonstrator.

Program name. MONTE (Timesharing BASIC).

Authors. Kenneth C. Young, Eastern Michigan University; David P. Doane, Oakland University (Michigan).

Modified by. David P. Doane.

Summary of content. Given an empirical distribution entered by the user, this program computes the mean and standard deviation of the population, draws random samples (the size and number of samples are specified by the user) and prints a histogram of the sample along with the mean and standard deviation of the sample means.

Educational objectives. The purpose of this program is to provide a demonstration of the central limit theorem which is intuitively appealing to students.

Specification of the computer's role. The program can be run as a classroom demonstration or used as the basis of a laboratory exercise.

Technical comments. The program was written in timesharing BASIC and run on a Burroughs 5500. It contains 258 statements which makes it too large for some minicomputers; a moderately sophisticated BASIC programmer can shorten its length considerably by eliminating options. Otherwise, it requires no programming by faculty or students.

Illustrative output:

THIS IS A MONTE CARLO SIMULATION WHICH DRAWS REPEATED RANDOM SAMPLES, WITH REPLACEMENT, FROM A POPULATION. YOU MAY SPECIFY THE GENERAL SHAPE OF THE POPULATION BY ENTERING FREQUENCIES FOR EACH OF 10 CLASSES (GROUPED DATA). ASSUME THAT THERE ARE A TOTAL OF 100 OBSERVATIONS TO BE ALLOCATED AMONG THESE CLASSES.

PLEASE ENTER DESIRED FREQUENCIES FOR EACH CLASS:

FROM	TO(NOT INC)	
0	10	?10
10	20	?10
20	30	?10
30	40	?10
40	50	?10
50	60	?10
60	70	?10
70	80	?10
80	90	?10
90	100	?10

THE HISTOGRAM FOR THIS POPULATION IS:

```

CLASS:
FROM TO      HISTOGRAM
----
0  10  *****
10 20  *****
20 30  *****
30 40  *****
40 50  *****
50 60  *****
60 70  *****
70 80  *****
80 90  *****
90 100 *****

```

POPULATION MEAN = 49.5785
POPULATION S.D. = 29.34

ENTER THE SIZE OF EACH SAMPLE (N)?4
HOW MANY SAMPLES OF SIZE 4 SHOULD I DRAW?100
SHALL I PRINT OUT THE MEAN OF EACH SAMPLE (Y OR N)?N

```

CLASS:
FROM TO      HISTOGRAM
----
0  10  *****
10 20  *****
20 30  *****
30 40  *****
40 50  *****
50 60  *****
60 70  *****
70 80  *****
80 90  *****
90 100 *****

```

MEAN OF ALL SAMPLE MEANS DRAWN SO FAR = 49.5839
S.D. OF ALL SAMPLE MEANS DRAWN SO FAR = 13.2309
NUMBER OF SAMPLES DRAWN SO FAR = 100

DO YOU WANT TO DRAW MORE SAMPLES FROM THIS POPULATION?Y
DO YOU WANT TO CHANGE THE SAMPLE SIZE?Y
ENTER THE SIZE OF EACH SAMPLE (N)?16
HOW MANY SAMPLES OF SIZE 16 SHOULD I DRAW?100
SHALL I PRINT OUT THE MEAN OF EACH SAMPLE (Y OR N)?N

```

CLASS:
FROM TO      HISTOGRAM
----
0  10  *****
10 20  *****
20 30  *****
30 40  *****
40 50  *****
50 60  *****
60 70  *****
70 80  *****
80 90  *****
90 100 *****

```

MEAN OF ALL SAMPLE MEANS DRAWN SO FAR = 49.618
S.D. OF ALL SAMPLE MEANS DRAWN SO FAR = 6.91159
NUMBER OF SAMPLES DRAWN SO FAR = 100

I NOTICE THAT YOUR HISTOGRAM IS CROWDED INTO ONLY A FEW CLASSES.
THIS MAKES IT HARD TO TELL WHETHER OR NOT THE DISTRIBUTION OF
SAMPLE MEANS IS REALLY BELL-SHAPED. THIS IS PROBABLY CAUSED BY
THE LARGE SIZE OF YOUR SAMPLES. WOULD YOU LIKE ME TO CHANGE THE
HISTOGRAM SCALE TO SHOW MORE DETAIL (Y OR N)?Y

```

CLASS:
FROM TO      HISTOGRAM
----
31 35  ***
35 39  **
39 43  *****
43 47  *****
47 51  *****
51 55  *****
55 59  *****
59 63  *****
63 67  *
67 71  *

```

DO YOU WANT TO DRAW MORE SAMPLES FROM THIS POPULATION?N

STOP

Availability. For further information concerning this program, availability of tapes, and an extensive student guide to the use of this and other statistics programs, write: David P. Doane, School of Economics and Management, Oakland University, Rochester, Michigan 48063.

APPENDIX E

Descriptive title. Power and Type II Error Demonstration.

Program name. POWER.

Author. Richard S. Lehman, Franklin and Marshall College.

Summary of content. For an input set of null hypothesis value, standard deviation, critical Z, and sample size, the program computes and prints Type II error probability and power for a range of alternative "true" population values, allowing easy plotting of the power function.

Educational objectives. The program allows students to explore the effect of variations in sample size, significance level, and population dispersion on the power of a one-sample statistical test.

Specification of the computer's role. Performs a large number of computations, including the integration of a segment of a normal curve, that make such an exercise impractical for most beginning students.

Technical comments. Written in BASIC for a UNIVAC 70/46. Includes an integration routine to avoid table look-up in computing normal curve areas.

Illustrative output:

ENTER YOUR NULL HYPOTHESIS VALUE?100
ENTER YOUR POPULATION STANDARD DEVIATION?15
ENTER THE CRITICAL Z FOR YOUR SIGNIFICANCE LEVEL?1.96
ENTER YOUR SAMPLE SIZE?10

STANDARD ERROR = 4.74342
CRITICAL BOUNDS FOR TEST OF H(0): U = 100 ARE
90.7029 AND 109.297

'TRUE' PARAMETER	BETA	POWER
55.00	0.000000	1.00000
59.50	0.000000	1.00000
64.00	0.000000	1.00000
68.50	0.000000	1.00000
73.00	0.000100	0.99990
77.50	0.002694	0.99731
82.00	0.033276	0.96672
86.50	0.187796	0.81220
91.00	0.524926	0.47507
95.50	0.842250	0.15775
100.00	0.950001	0.05000
104.50	0.842251	0.15775
109.00	0.524921	0.47508
113.50	0.187795	0.81221
118.00	0.033276	0.96672
122.50	0.002694	0.99731
127.00	0.000100	0.99990
131.50	0.000000	1.00000
136.00	0.000000	1.00000
140.50	0.000000	1.00000
145.00	0.000000	1.00000

RUN ANOTHER (YES,NO)?NO

STOP

Availability. For a listing and an example assignment using the program, contact: Richard S. Lehman, Department of Psychology, Franklin and Marshall College, Lancaster, Pennsylvania 17604.

REFERENCE NOTES

1. Lehman, R. S. The use of the unknown in teaching statistics. Paper presented at the meeting of the Eastern Psychological Association, 1972.

2. Suziedelis, A. SIFT: Statistics by interaction with files from the terminal. Mimeographed paper, Catholic University of America, Washington, D.C., 1972.

3. Main, D. W. A computer simulation approach for teaching experimental design. Paper presented at the meeting of the American Psychological Association, 1971.

4. Rajecski, D. W. EXPER SIM. Mimeographed paper. Department of Psychology, University of Michigan, Ann Arbor, 1972.

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NOTES

1. To obtain more information about SPSS, write: National Opinion Research Center, 6030 South Ellis Avenue, Chicago, Illinois 60637. A magnetic tape of the program costs \$500. Maintenance and updating service is \$300 per year.
2. R. Anderson, personal communication, July 1974.
3. To obtain further information about XTAB9, write: James Sakoda, Department of Sociology, Brown University, Providence, Rhode Island 02912.
4. To obtain further information about MINITAB, write: Thomas Ryan, 219 Pond Laboratory, Pennsylvania State University, University Park, Pennsylvania 16802.
5. To obtain further information about EXPER SIM, write: Dana B. Main, Department of Psychology, University of Michigan, Ann Arbor, Michigan 48104.