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ABSTRACT

This paper, prepared for a symposium on the interface of computer sciences and statistics, addresses the use of computers in the teaching of statistics. Two principle means of integrating the fields of computer science education with education in statistics are identified: (1) integrating the content of statistics in courses on computers, and (2) using computers as a method of statistics instruction. The first half of the paper provides a review of six textbooks in current use; three present statistical concepts and problems as examples of programming problems, while the remaining three are designed to teach statistics using computers as an aid in problem solving. The second half of the paper is devoted to a review of research and evaluation findings related to computer assisted instruction, simulations, and both interactional and non-interactional statistical packages. A bibliography containing 62 titles is included. (SD)

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ABSTRACT

Conceptually, the current use of computers has taken two forms in the teaching of elementary statistics: integrating the content of statistics with that of computers; and integrating methods of instruction of statistics by use of computers. In the first half of this paper, three computer language textbooks are reviewed. Each uses statistics as a content area presenting programming problems. Also, three textbooks which focus on learning statistics using the computer as an aide are reviewed. The second half of this paper surveys six published articles that evaluate courses employing "hands-on" computer instruction (CAI) and also, many published articles evaluating courses employing a demonstrational mode of instruction. The generation and use of simulated experimental data and interactive vs. non-interactive computerized statistical packages are reviewed. Extensive recommendations for integrating computers into the teaching of statistics are included. Sixty-two references.

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Current Use of Computers in the Teaching of Statistics

Within the last five years a revolution has occurred in all courses that require calculations. From primary grades to post-doctoral study, the inexpensive electronic pocket calculator has had a pervasive impact upon the curricula. But, just as the introduction of calculators in courses of statistics greatly influenced the development of the analysis of variance and experimental design (Evans, 1973), so too can we expect the introduction of inexpensive, programmable computers to have a greater influence on the development of statistical theory, practice, and teaching.

The impact of computers on statistical theory is best exemplified by the recent work on matrix decompositions, generalized inverses, and multivariate analysis (Golub, 1969; Rao, 1966; Kshirsagar, 1972). Many of the classical, hand-calculator based methods have now become obsolete or have been revised with the advent of computers (Golub, 1969). The computer has already changed statistical practice. Extensive plotting of data and residuals is quite common. There has been a shift of emphasis from general tables of statistical functions, to direct evaluation of discrete values. It is unusual not to see "p-values" reported in research articles. Whereas, ten years ago ".05", ".01", and "ns" were commonplace. Jack-knifing is an example of a statistical technique whose widespread application would not have been seriously considered before the advent of computers, but it is now included in the curriculum. Evans (1973) gives an excellent review of the influence of computers on modern statistics.

Yet, for all the impact computers have had on the theory and practice of statistics, only recently have there been attempts to integrate the use of computers with the teaching of elementary statistics. The purpose of this article is to explore the current use of computers in the teaching of elementary statistics. Conceptually, this exploration will be in two forms. First, the various means of integrating computers into the content of elementary statistics will be examined. Criteria for identifying the strengths and weaknesses of published textbooks and computerized statistical packages will be examined from the viewpoint of content relevance. Second, the various methods of implementing the integrated content of statistics and computerized statistical packages will be surveyed. Although the principal emphasis is on an introductory non-calculus course, most of the methods described in the second part of this paper are useful in higher level courses in statistics and research methodology.

Integrating the Content of Statistics and Computers

Recent introductory textbooks attempting to integrate statistics with computers appear to take two forms. In the first form, the object is to learn a computer language, where statistics is used as a content area presenting program problems. The second form that many recent introductory statistical textbooks have attempted, focuses on learning statistics using the computer as an aide. In these textbooks, a higher order computer language or a "canned" statistical package is used as a vehicle facilitating rapid computation and/or insight of statistical texts and procedures.

Introductory Computer Programming Textbooks with Statistics

Three introductory programming textbooks using statistics as a vehicle for teaching FORTRAN are: Introductory Statistics with FORTRAN by Kirch (1973) reviewed by McCabe (1974); FORTRAN Programming for the Behavioral Sciences by Veldman (1967); and Introduction to Statistics and Computer Programming by Kossack and Henschke (1975). All three of the textbooks attempt to complement and enhance statistical development. However, each of the three textbooks overwhelming emphasize the learning of FORTRAN at the expense of the statistical content. Each of the texts orderly organizes the introduction of FORTRAN from I/O media to program libraries, from simple FORTRAN statements to branching, and from simple manipulation of constants to complex operations upon arrays. The incorporation of previous statistical exercise programs as subroutines of subsequent statistical programs is common to all three texts. Such exercises provide a sense of accomplishment and utility in programming. In reality, statistical programs are built from repetitive, meaningful components much in the same way that a statistician's repertoire of designs and analyses originates. However, it is questionable whether the content of such texts should be used in introductory statistics courses. Such texts would better serve the teaching of computer languages. On the other hand, perhaps an exciting use of these texts would be as a language option for terminal degrees in the behavioral sciences.

All too often, when computer applications enter the behavioral research process, it is via a computer programmer and perhaps a a consulting statistician. This mode of adaptation encourages the behavioral researcher to relate to the programmer and statistician as one might relate to a vending machine or a taxi cab. That is, when a researcher excludes knowledge of a computer language from his own skills, he leaves a critical part of his research in the hands of another (Erickson & Jacobsen, 1973). Furthermore, he has no means of determining whether or not the computer analysis was accurate or not, nor whether its expense was justifiable. In short, a course from a computer/statistics textbook could be taught in such a way as to deepen the student's understanding of various statistics and the theory behind them rather than teaching that the computer is just another type of desk calculator.

Following are reasons for using a common language like FORTRAN in teaching statistics (Andrews, 1973):

1. Programmer is aware of the strengths and weaknesses of numerical algorithms.
2. Programmer has control over input/output and calculations.
3. Greater efficiency and flexibility in handling data and core allocation.
4. The higher the language level, the more severe the constraints on input/output (I/O).

Following are reasons for not using a common language like FORTRAN in teaching statistics:

1. Excessive use of class time to learn FORTRAN.
2. Time that could be used on theory is squandered explaining tedious programming problems.

3. Rarely will a student program be correct in less than ten runs. A very expensive exercise.

Introductory Statistical Textbooks with Computer Applications

A classic in the field is Lohnes and Cooley's (1968) Introduction to Statistical Procedures with Computer Exercises. In general though, the content of Lohnes and Cooley's text is too advanced for an elementary statistics course. An elementary supplement that follows in the tradition of Lohnes and Cooley is A Computer-assisted Approach to Elementary Statistics: Examples and Problems by Bulgren (1971). The book can be used as a supplement to introductory statistical texts written by Adler and Roessler (1968), Freund (1967), Hoel (1966), Huntsberger (1967), or Mendenhall (1971). The strong point of Bulgren's supplement is the insight a student can gain through the simulating and manipulative capabilities of the computer. The book consists of exercises to be solved by either writing FORTRAN programs or punching the programs in the appendices. Each exercise consists of the following four parts: statement of the problem, input, output, and discussion and questions. The intuition that a student can gain is exemplified by the chapter dealing with statistical inference- large sample methods. An exercise in that chapter compares and contrasts the 5% and 1% confidence interval of μ when σ is known verses unknown for a sample of 10 as compared to 40 pseudo-randomly computer generated N(10,100) observations. This experiment is repeated 100 times. The purpose of the exercise is threefold. First, the exercise is to show that in repeated sampling, the estimate of the population mean will fall in 95%± of the 5% confidence intervals.

Second, when the population variance is unknown and when the sample size is large, the experimenter can rely heavily on the degree of probability (confidence coefficient) established prior to running the experiment. Third, as the sample size increases within the experiment, the better are the point estimates $\bar{x}$ and s^2 of μ and σ^2. A complete statement of the problem, input, output, and discussion and questions may be found in Appendix A.

The overlaying of Bulgren's supplement on an elementary text would be a compromise between the strict computer programming texts on statistics and the following texts. Each of the following textbooks use statistical packages or simple "canned" subroutines: Introduction to Statistics and Data Analysis with Computer Applications - I & II by Morris and Rolph (1971); Statistics for Education: With Data Processing by White (1973) reviewed by Wolf (1974); and Statistical Analysis: A Computer Oriented Approach by Afifi and Azen (1972) reviewed by Andrews (1974). The emphasis of Morris and Rolph's test is on how and when to use existing statistical techniques. The authors state that "computer use replaces theorem proving". In essence the pre-calculus text covers the appropriate use and sequencing of JOSS programs and the SNAP/IEDA package. The authors' statement indicates the increasing amount of statistical analysis done by researchers with a modest amount of statistical experience. Packaged statistical programs have made this possible.

Such negligent use of statistical packages manifests the immediate need for a statistical text that truely incorporates the computer's potential. Regretfully, Afifi and Azen's text does not satisfy this pressing problem. Only brief mention is made of software packages in the first chapter of their book. The content and computational procedures of the remaining chapters closely parallel traditional texts. Aside from the listing of two large data sets, the book contains no computer output. Where convenient, the authors refer to the Biomedical (BMD) and Scientific Subroutine Package (SSP).

Much to the credit of White's textbook is the interweaving of data processing into statistics. Extensive use of photographs and diagrams presents a through overview of computer hardware. Computer programs that require only a simple control card and FORTRAN format specifications are included in the appendix. Data processing exercises in the text provide practice in the use of various statistical procedures. The data for the exercises is in the appendix. A great deal of emphasis is placed upon educational examples.

Probably none of the books mentioned above would satisfy the needs of every instructor. However, this small number of texts are among the first to recognize the interelationships of statistics and computers. As long as statistical content is not sacrificed, then experimentation of this type has the potential of producing significant improvements upon the quality of elementary statistics courses.

Following are guidelines for integrating statistics with computers in textbooks:

1. Cost-efficiency is of prime concern in selecting a general statistical package vs. "canned" programs. Student programming in a low level language like FORTRAN is very expensive.
2. The emphasis on computers should be on large data set manipulation and visual display (plotting, histograms, residuals).

3. Simulation of data with pseudo-random computer generated numbers is expensive. Alternative non-computer simulations should be used where it is feasible.
4. Statistical techniques antiquated by the computer should be dropped from textbooks if the techniques contribute nothing to statistical content eg. short-cut approximations.
5. I/O of statistical programs should be included in textbooks.
6. Textbook authors should provide machine readable data bases for text and exercises.

Following are reasons for interweaving large statistical packages like BMD, SSP, SPSS, etc. into textbooks:

1. Programs are shorter and easier to write.
2. Programs usually work the first time.
3. Typically such programs produce results of several different types of calculations that a programmer might not have bothered to include in his own program.
4. Writing programs to perform data manipulations in languages like FORTRAN can be tedious.
5. The I/O is fairly uniform from one installation to another.
6. Virtually all analyses are available.
7. Most researchers publish results generated by large statistical packages.

Following are reasons for not interweaving large statistical packages into textbooks:

1. The textbook could not be used at the majority of Universities due to the large computer support system required.

2. Even one run of a program by a student is very expensive.

3. Student fails to grasp theoretical understanding that results from writing his own program (Abranovic, Ageloff & Fredrick, 1974).

4. Large statistical packages confuse the student with results that are explained in advanced courses.

Following are reasons for interweaving simple "canned" statistical packages into textbooks:

1. Unnecessary to learn a computer language.

2. Programs require small amount of core and can be run at most installations.

3. Saves class time in teaching mechanics.

4. Programs are task specific, hence more efficient and less expensive to use.

5. Procedures for using the package could be easily taught in less than two hours.

6. Provides easy access to standard techniques.

Following are reasons for not interweaving simple "canned" statistical packages into textbooks:

1. Mindless use of statistical programs replaces the intelligent use of theory (Wallace, 1969).

2. Canned programs can be time consuming if the data output of one program is not compatible with input of other programs.

3. If the data output of one program conforms to the input of another, then data must be stored in a more expensive form than for higher level, more comprehensive statistical packages eg. computer cards.

4. Canned programs are often machine dependent.

ADDITIONAL TEXTBOOKS: Brier, Alan, & Robinson (1974); Dixon & Nicholson (1974); Hodges, Krech, & Crutchfield (1975); and Rattenbury & Pelletier (1974).

Methods of Instruction by Integrating Statistics and Computers

As we have seen, the use of computers in statistical content has taken on at least two forms; emphasis on a computer language at the expense of statistics or vice versa. In the following discussion it will become clear that the computer can serve many facets in the process of statistical instruction. For convenience, the first half of this section will deal with published evidence of courses employing a "hands-on" computer mode of instruction (student) and courses employing a demonstrational computer mode of instruction (teacher). The second half of this section will deal with the generation and use of simulated experimental data and interactive vs. non-interactive statistical packages.

"Hands-on"

One of the most all encompassing methods of "hands-on" instruction of theoretical material is Computer Assisted Instruction (CAI). Wassertheil (1969) successfully incorporated CAI into the laboratory portion of an introductory statistics course. In her study, the main use of CAI was to individualize instruction. Each student progressed at his own pace. The computer was programmed to interact with a student at a remote teletype. If a student's response to a programmed computer question was correct the computer would go to the next question, present new material, skip simpler material, or go to more complex matters based on the previous rate of progress of the student. On the other hand, if the student's response was incorrect, the computer would either "present tutorial material, review concepts, give hints, refer to the text or tell the student to go home and study some more". Throughout the process, the computer recorded the performance of each student. All of the above concepts are common to CAI.

The CAI Problem Laboratory in Statistics and STATS Workbook of Problems were developed by IBM's T. J. Watson Research Center in Yorktown Heights, New York. The workbook was used in conjunction with Alder and Roessler (1968). Thirteen of twenty-six students in Wassertheil's "Introductory Statistics" volunteered to schedule one hour of terminal time in lieu of the usual 75 minute weekly laboratory. Wassertheil went over the homework problems and answered questions of the control group in the laboratory sessions. Both groups turned in weekly assignments from the workbook. The cumulative grade point average and examination scores for both groups are exhibited in Table 1.

Table 1

Grade Point and Examination Score Means and Standard Deviations of Groups in Wassertheils Study

	Non-computer group		Computer group	
	μ	σ	μ	σ
Cumulative Average	2.53	.27	2.63	.40
First-hourly Exam	85.2	8.9	85.7	13.1
Second Exam (multiple-choice)	81.5	18.5	84.0	9.1
Second Exam - complete	65.9	18.0	74.9	14.2
Final Exam (multiple choice)	62.3	12.4	68.9	12.2
Final Exam - complete	70.1	10.7	74.5	7.9

There were no statistically significant differences between the groups on any of the measures. The computer group did somewhat better on the second examination and the final examination. The average amount of terminal time used to cover eight chapters was 10.1 hours with a standard deviation of 3.9 hours. Perhaps the most positive result of Wassertheil's study was that one 75 minute class period per week could be eliminated without deterioration of student performance. The benefit of CAI would be the freeing of the instructor for individual student contact or other duties.

A similar study was conducted by Forsythe and Bleich (1973). Twenty-five students used computer terminals to interact with a CAI program that:

1. Helped them learn routine material, such as definitions and basic processes.
2. Enabled each to see if he had mastered the important content of the text by presenting short answer questions and responding to his replies with specific references to the text.
3. Removed much of the drudgery of the statistics laboratory by doing the calculations after the student has shown that he can do them once.

A great deal of the CAI interactive program is included in the article by Forsythe and Bleich. Although a control group of twenty-five students were randomly selected, Forsythe and Bleich did not report any comparitive evaluation other than that those who used the terminals were "overwhelmingly positive". The authors concluded that "the computer can be used beneficially to help the teaching of a 'service' statistics course. By shifting the routine parts of the lecture and laboratory to an interactive computer program, we are able to increase interest, add extra material to the curriculum, while decreasing both student classroom time and total teacher time."

An individualized statistics course for sociology majors (Howze, 1973) went a bit further in extracting the teacher from the classroom. There was no lecturing in Howze's course. Students worked independently at their own pace and sought the teacher's help when they encourtered difficulties. The students were explicitly told what tasks must be completed and the quality of performance necessary for various letter grades. The computer was used to generate a unique sample of data for each student's homework problems. Students then used the computer as an equivalent to a desk calculator to solve the homework problems. Upon turning in the homework a computer-generated report detailed the correct answers and key intermediate calculations.

The teaching and testing in the course was done by the computer. Students read assigned chapters in the text and then interacted at a terminal with a CAI program written in BASIC. The CAI contained both text and branching questions. When a student felt he was ready to take an examination, he logged his ID# and the computer generated and displayed on a cathode ray tube (CRT) 20 questions randomly sampled from a population of 100 questions. The student was allowed to retake an examination until he was satisfied with his score. No hard-copy of any examination was allowed. Of course, the number of retakes and scores were automatically recorded by the computer. Thus, the instructor could use the computer's record of the student's progress as a diagnostic tool. Howze reported only the preliminary results of his study. There were no comparitive groups.

Over twenty CAI programs in statistics have been reported by Lekan(1971). The majority of these programs were short course segments on a variety of specific topics written in languages that were often machine specific. An example, is the CAI short course on the theory and application of the product-moment family of correlations written by Tira (1970). Tira found that the short course benefited students who initially had the least understanding of the fundamentals of statistical concepts.

The following two studies completely incorporated the computer into graduate statistical service courses. The first study by Wagner and Motazed (1972) utilized the Proctorial System of Instruction (PSI) combined with a Computer-Based Support System (CBSS). PSI consists of the following components (Keller, 1968):

1. Self-paced according to student's ability and time available.
2. Demonstration of complete mastery of a unit before proceding to the next unit.
3. Stress upon written communication in student-teacher communication.
4. Use of lectures and demonstrations as vehicles of motivation, rather than sources of critical information.
5. Proctors provided tutoring, repeated testing, and immediate grading.

The CBSS consisted of interactive statistical subroutines and instructional modules. The modules were conversational time-sharing FORTRAN programs. The primary topics of the modules were statistical distributions, experimental verification of theory and methods, and data collection, analysis and interpretation.

Three proctors operated the system. The proctors monitored 30 to 40 minute tests taken by a student when he felt he was ready to be tested. Immediate grading and personal help with missed questions were other functions of the proctors. Oral examinations were also a feature of this study. The student could not progress to the next module unless he passed the proctored examination with 100% accuracy. If a student did not complete the course within a semester he received an "I". Another feature of PSI was the inclusion of five audio cassette taped lectures into the system. The primary purpose of the lectures was "motivational and to import the professor's philosophy and methods of oral communication."

No comparitive results were gathered in the study. A student questionnaire supported the belief of the superiority of Wagner and Motazed's procedure over a "standard" statistics course. The distribution of grades in the last reported year of the study was: 10% withdrew; 85% earned A's; and 5% earned B's. The authors were convinced that "all students learned more , learned more throughly, were more satisfied, were more motivated and enthusiastic and overall much better trained."

The second study by Skavaril (1974) incorporates the computer into all phases of instruction in an introductory service statistics course. In his study, the computer not only provided tutorial CAI support, but also generated statistical exercises and answers, and provided subroutines for complete data analysis. Skavaril lists and briefly describes twenty-nine CAI modules, nine exercise-generating programs, and twenty-one data analysis programs used in his system. The programs were written in IBM's Coursewriter III, PL/I and FORTRAN IV, and Conversational Programming System (CPS) respectively. Usually six half-hour meetings per quarter were required for the administration of laboratory quizzes. An introduction to the course and computer base required four one-hour lecture periods. Otherwise, each student proceeded at his own pace through the CAI modules. The instructor answered questions individually. The only constraints were the announced dates of examinations. All students took the same examination at the same time.

Students accessed the modules by means of interactive, on-line mode, terminals. Each student was assigned an ID# which allowed the computer to identify that particular student and to restart the student at the last point worked on in a module. Students were permitted to skip or to repeat a module. In general though, the students completed the modules in sequence (see Appendix B). The program kept a record on each student. The record included a list of modules completed, total time spent on the course, and performance scores on quizzes within modules. These data could only be accessed by the instructor and were used to produce weekly reports on student progress. Skavaril's description of the structoring of each module is so clear that it is included as a model.

> "In general, each module has been constructed according to the following pattern. The student is first given a brief description of the modules content and a statement of the approximate time required to complete the module. The student is then asked if he wishes to work on the module. If the student enters a negative response, he is informed how to return to the module subsequently should he change his mind and decide to take the module. If he responds that he does wish to take the module, the subject matter of the module is presented to the student in an interactive, question and answer format. Each student is supplied with prepared handouts to which he is required to refer from time to time while working within a module. The handouts are used so as to minimize the amount of typing done by the computer terminal. During the presentation of the module's instructional material, wrong answer processing is employed in a diagnostic manner in order to inform the student why a particular response was incorrect. Frequently, throughout each module, the student is given the option to receive additional

> instructional material in the form of supplementary and complimentary material and numerical examples. After the instructional material has been presented, the student is assigned his laboratory work for the module and told which of the CPS programs are relevant for the particular analysis at hand. Next, the student is informed as to which chapters in the text (Li, 1968) contain related material. Then, the student has the option of working practice problems and answering review-type questions and/or taking an optional quiz. After completing the quiz, the quiz score is presented together with a statement of the instructor's evaluation of that score. The correct answer for each quiz question incorrectly answered is also displayed. Throughout all modules, the student is allowed use of the "calc" command for miscellaneous computations".

Skavaril compared the time expended and examination scores for the computer based group with a conventional lecture-laboratory group for the same course. The results are presented in Tables 2 and 3.

Table 2

Average Total "in-class" Hours

Activity	Computer-Based (70 Students)	Lecture-Laboratory (50 Students)
Lecture	3.2	32.8
Laboratory	3.0	20.0
CAI	21.7	0.0
CPS	8.0	0.0
Exams	3.4	3.4
Total Hours	39.3	56.2

Table 3

Comparison of Final Examination Scores

Statistic	Computer-Based (70 Students)	Lecture-Laboratory (50 Students)
Sample mean	60/100	57/100
Sample variance	270.68	363.32
Standard error	1.97	2.69

Clearly, a great deal of time was saved at no expense to learning as measured by the final examination. In addition, the author notes that the exercise-generating and CPS programs, provide additional gains, since the student receives a unique set of data; cribbing is eliminated. Freeing the student of the tedium of calculations allows him to analyze several sets of data and "to build, by comparing statistics between analyses, empirical evidence concerning the underlying distribution of those statistics."

Demonstrational

In essence, this section simply questions to what extent student involvement with the computer is cost-efficient in the teaching of an elementary statistics course. For example, is it necessary that every student individually simulates the Central Limit Theorem, or individually simulates the meaning of "5%" statistical significance by repeating an experiment 100 times on the computer as described earlier in Bulgren's supplementary textbook? Filming or video taping these computer simulations could provide the same learning at far less cost. Another question is, how cost-efficient is it to generate unique data sets for each individual's homework problem? Is the generation of such data sets to benefit the student or simply to assure the instructor that each individual completed his own work? These questions truly relate to the merits of the statistical laboratory.

Each of the studies thus far described in this article appeared to develop from the desire to eliminate distracting computations from statistics courses. Previously, these laborious tasks were relegated to the statistical laboratory. The computer has been offered as the computational genie for both student and instructor. And thus, more often than not, the computer has been introduced and utilized in the statistical laboratory.

Considering the evolution of the computer in the last twenty years, it is obvious that computers initially were viewed as sophisticated calculators and thus their proper place was in the laboratory situation. In manyinstances the laboratcry was viewed simply as problem sessions. Now that computers are more flexible and diverse in capability, their use should be objectively incorporated into the lecture and laboratory situation. That is, the appropriate use of computers in a course occurs when the objectives of the lecture and laboratory are re-examined in terms of the possible contributions of the computer.

Certainly, a student's ability to add, multiply, and divide on a desk calculator is not the main objective of a traditional statistical laboratory situation. In the same way, a student's ability to push buttons on a console or type a program name on a teletype and then slavishly follow a set of directions in order to receive a few numbers or to progress to the next question that a proctor already has the print-out of, is not the objective of a statistical course. A programmed text with solved problems would be far less expensive. Instructor controlled computer usage to meet specific course objectives could control the costs.

The instructor can do many things with the computer to provide useful information for the statistics classroom or laboratory. A compiled set of statistical problems with computer solutions eliminates expensive student use of the computer and unnecessary learning of the mechanics of programming. Computer graphing of theoretical distributions, pupulations, samples, or transformations can easily be compiled into booklet form available for student purusal. Wegman and Gere (1972) produced a workbook of problems with computer solutions and a set of forty slides illustrating a variety of distributions, densities, and histograms available at cost.

Many recent innovations have increased the availability of computers for in-class demonstrations and experiments. Minicomputers, phone line teletype and video hookups, hard-copy off of CRT's, and kinescope projection provide the instructor with the option of using the computer in class as a supplement to the lecture. Recent articles by Edgell, Lehman, Starr, and Young (1975), Kanji (1974), Tanis (1973), and Abranovic, Ageloff, and Fredrick (1972) offer a large number of methods for the use of the computer or simulating equipment as supplements to a course in statistics. An innovative method of discussing and using the Poisson distribution follows (Wegman and Gere, 1972):

> "Instructor A purchased two bags of chocolate chip cookies, both were the same brand but on one bag there was a large seal proclaiming 'more chips'. The students received one cookie from each bag and were asked to count the number of chips. (The students were allowed to dispose of the residue as they deemed fit.) The results were tabulated and tables of the Poisson distribution were calculated using an APL terminal. The results were duplicated (mimeographed) for student use. The students were asked:
>
> 1. Whether the distribution of chips seemed to fit a Poisson.
> 2. Whether the results from the two bags of cookies seemed to indicate a difference between the two.
> 3. Whether the results of either bag conformed to the manufacturer's national advertising, claiming an average of sixteen chips per cookie.
>
> With this history, we see two aspects of the computer use in an elementary course. Firstly it serves in a demonstration mode and secondly its speed and accuracy allowed Instructor A to compile materials based on an actual in-class experiment."

The computer has its rightful place in the instruction of statistics. It is not only important that the instructor make thoughtful use of the computer; it is also important that student use of the computer be thoughtfully arranged by the instructor.

Some of the reasons to use computers to aid in learning or teaching statistics are as follows (Andrews, 1973):

1. Computers are among the tools of the practicing statistician.
2. Calculations are fast and typically if one set is correct the remaining sets are also correct.
3. Data in large quantities may be feasibly stored and organized.
4. Computers may be used as "teaching machines" for factual information.
5. Computers are fun; they can enliven some aspects of a problem.

Some of the reasons not to use computers to aid in learning or teaching statistics are as follows (Andrews, 1973):

1. No money is available to finance extensive computing by students.
2. The available computer is inadequate or inefficiently operated.
3. The available software is inadequate.
4. Computers take longer than hand calculations.
5. The student should not become software or machine dependent.
6. 95% of computer output is useless, and 99% of computer output is tedious to read.
7. Computers create a barrier between students and data. Gross errors result.
8. Students may confuse computing with analysis.

Simulation

Not only can the computer eliminate the tedium of computations, it can also eliminate the collection, input, storage, and manipulation of data.

A computer can be a fancy random number generator. Statistical designs can be specified for populations of known parameters. Following is a discussion of some of the more recently reported simulation programs. STEXSIM, developed by W. Thomas (1972) in FORTRAN generates data for factorial designs having up to seven random or fixed main effects. Lehman's (1973) programs generate data for "single-variable independent-group designs, generalized analysis of variance designs, ... for both bivariate and multivariate experiments". The programs were written in FORTRAN. Salmon and Tracy (1975) developed four programs that generate exercises on z-scores, Pearson product moment correlation with regression or matched groups t-test, independent groups t-test, and chi square. The student exercises consist of generated data and problem instructions. A solution corresponding to the exercise is produced for the instructor. Intermediate steps in the solution are included. To generate exercises, the instructor enters such information as the number of exercises to be produced, the difficulty level of the exercises, and the parameters of the population into the appropriate program. The programs were written in BASIC. A similar package of four modules was written by D. Thomas (1971). Entitled STATSIM, these modules were designed for terminal use. The exercises relate to descriptive and inferential statistics for chi square, t-, z-, and F-distributions.

An extensive data generation system, EXPERSIM (Main, 1971), is a set of sophisticated computer simulation models for various experimental situations in specific subject areas, e.g. imprinting, drug research, motivation. Each simulation includes a complete description of the experimental setting, built in controls, number of variables that can be manipulated, and the sample data. The student may then analyze the experimental data by requesting statistical routines. EXPERSIM was written in FORTRAN. Exxon Education Foundation is offering grants to institutions desiring to implement the system. In fact, each of the simulation programs discussed in this section are available from the respective authors.

A comprehensive graphic display system was developed by Beaujon (1970). Computer generated graphic and alphanumeric information can be displayed on an IBM 2250 CRT. The system can simultaneously display the probability density function, cumulative distribution function, or frequency distribution of a random sample from any of the following distributions: discrete uniform, binomial, poisson, hypergeometric, continuous uniform, triangular, normal, gamma, exponential, Cauchy, beta, Student's t, chi square, and F.

Using Beaujon's display system, Wegman (1974) projected 28 slides illustrating various distributions to 18 introductory statistics students two days prior to their third examination in the course. The 19 minute slide show was "accompanied by a simple description of the slides". The 18 control students were called in for the remaining 75 minute review, question and answer session. The material Wegman reviewed included a discussion of the properties of the distributions just shown the "slide group" as well as other material relevant to the upcoming examination. A ten-question true-false quiz was included in the third examination and final examination. Wegman found that "a very modest amount of supplementary graphical material of the type made available by the graphic display packages provides a significant ($p < .005$) increased score for a short term."

Following are suggested (Andrews, 1973) ways for using a system of statistical packages.

1. Data collection and handling. Basic operations such as sorting

or listing can aid in the preparation and distribution of examples. Data may be given to students on cards ready for further computation.
2. Data plotting: histograms, scatter plots. For large data sets, this plotting is eased considerably by the use of computers.
3. Computations which are part of a more refined analysis, eg. analysis of variance.
4. The above may be done by the teacher or by the students.
5. Very, very rarely, the computer may be used to generate pseudo-random data for subsequent analysis (recycling in the "garbage in garbage out" principle). Such data are useful for illustrating the properties of a particular technique; they do not illustrate many of the problems of less idealized situations.

ADDITIONAL REFERENCES: Cassel, 1971; Dixon, 1971; Fachnie and Schillace, 1973; Finn, 1971; Michael, 1973; Spirer, 1972.

Interactive vs. Non-interactive Statistical Packages

Large statistical packages such as BMD (Biomedical; Dixon, 1968), IMSL (International Mathematical and Statistical Language, 1975), SAS (Statistical Analysis System; Barr and Goodnight, 1972), and SPSS (Statistical Package for the Social Sciences; Nie, Bent, and Hull, 1970) are prohibitively expensive (core and external device requirements) for student use in introductory statistics courses. The amount of core and the use of disk and magnetic tape rapidly increases the cost of processing such packages.

Smaller packages have been developed. MINITAB (Ryan and Joiner, 1973) and OMNISHRIMP (Harris, Swanson, and Duerr, 1974) have supplanted the much slower OMNITAB (Swanson, Ledlow, and Harris, 1973). Both are smaller, faster systems which run on medium sized computers. These packages are usually "batch" processed.

A recent release by Koh (1975) of TUSTAT-II (Tutorial system for statistics with time-sharing computers) and STRAP-II (Statistics system for research and production with time-sharing computers) provides 140 statistical routines in BASIC. Each source program requires less than 4K words. The utility of

Koh's programs is clear in his reflection that

> "usually researchers who are comparatively naive in statistics or computer knowledge complain the most. After carefully observing all possible aspects of interactions between consultees and consultants, I began to see that the time-sharing terminal and a sophisticated statistics system such as STRAP would reduce some of the communication gaps and complaints. By letting the research scientists do some of their own simple statistical analysis themselves, they begin to understand what kind of work there is to be done to get statistical analysis. Also, the STRAP users are willing to spend their own time at the terminal to get instant response instead of asking their consultant."

Another interactive statistical package is STP (Statpack; Houchard, 1974). Written in FORTRAN, the package has 16 overlays. It is an integrated, interactive package written for terminal use. STP allows the user to issue simple commands for data analysis and it will prompt him for necessary information. When questions of a procedural nature arise, the user may ask for an additional explanation by typing "HELP". The standard output device is the terminal, but output may be channeled to the line printer. STP is unique in that you may issue a command to store your data on disk or tape. You could then "read" it out of storage and manipulate it in core at some latter date.

The statistical packages mentioned briefly in this section have not been evaluated in form or substance. The Statistical Computing Section of the American Statistical Association is currently studying strengths and weaknesses of statistical programs within packages. But, over-and-above the calculations within a statistical analysis are the sequencing of statistical analyses. This dimension of a statistical package may be considered to be the degree in which the computing is interactive, ie. the number of times the analyst directs the computation. Andrews (1973) suggests the following considerations for a non-interactive package:

1. These are typically very similar to subroutines and thus require little introduction for the FORTRAN programmer.

2. They require no change in the existing hardware if computer core is large enough.
3. The output is typically voluminous bringing many things to the attention of the analyst.
4. The output is standard to other users of the same programs. Hence it is easily read by others.
5. The programs are standard, hence the calculations are more likely to be trusted by others.
6. To analyze output requires time and thought. There is little or no time advantage in using an interactive system if there is an efficient method of running standard jobs.
7. Interactive systems require sufficient hardware and software to support some sort of time sharing system. This may not be available.

Considerations for using interactive systems.

1. The analysis of data is interactive! Interactive computing reduces the time required for this interactive process.
2. Interactive systems provide greater flexibility in analysis.
3. They bring the analyst and data closer together so the analyst has a better "feel" for the data.
4. Output typically is brief presenting primarily what was asked for. It raises few (perhaps extraneous) questions for the user.
5. The interactive system can guide the investigator through the analysis and may help to prevent gross errors.

CONCLUSION

The computer has progressed from a simple calculator to a sophisticated interactive device capable of instruction. The advent of inexpensive, programmable computers has had and will continue to have a truely great influence on the development of statistical theory, practice, and teaching. But, the successful introduction of computers into a statistics course will occur only when the objectives of the course are re-examined in terms of the possible contributions of the computer. For if computer usage is not aimed directly at fulfilling course objectives, then it is highly probable that the use of the computer will be inefficient and impractically high priced. Thus, it is not only important that the instructor make thoughtful use of the computer, it is also important that student use be thoughtfully arranged by the instructor.

REFERENCES

Abranovic, W., Ageloff, R., & Fredrick, D. Time-sharing computer system as a teaching tool. American Statistician, 1972, 26(1), 34-38.

Afifi, A. & Azen, S. Statistical Analysis: A computer oriented approach. New York: Academic Press, 1972.

Alder, H. & Roessler, E. Introduction to probability and statistics, 4th ed. New York: Freeman & Co., 1968.

Andrews, D. Developing examples for learning statistics: Data and computing. International Statistical Review, 1973, 41(2), 225-228.

________. Book review of "Statistical analysis: A computer oriented approach by Afifi & Azen". Journal of the American Statistical Association, 1974, 69(345), 279.

Barr, A. & Goodnight, J. A user's guide to the statistical analysis system. Raleigh, N. Carolina: North Carolina State University, 1972.

Beaujon, H. An interactive, graphical display system for illustrating elementary properties of statistical distributions. Unpublished Masters thesis, Chapel Hill, N. Carolina: North Carolina University, 1970.

Brier, A. & Robinson, I. Computers and the social sciences. New York: Columbia University Press, 1974.

Bulgren, W. A computer-assisted approach to elementary statistics: Examples and problems. Belmont, California: Wadsworth Publishing Co. Inc., 1971.

Cassel, R. The precision-power-gradient theory for teaching basic research statistical tools to graduate students. Paper presented at American Educational Research Association, New York, February, 1971. (ERIC ED 048 360)

Dixon, W. J. (ed.). BMD: Biomedical computer programs. Los Angeles: University of California Press, 1968.

________. Notes on available materials to support computer-based statistical teaching. Review of the International Institute, 1971, 39(3), 23-26.

Dixon, W. J. & Nicholson, W. (eds.). Exploring data analysis: The computer revolution in statistics. Berkeley, California: University of California Press, 1974.

Edgell, S., Lehman, R., Starr, B. & Young, K. Computer aides in teaching statistics and methodology. Behavioral Research Methods & Instrumentation, 1975, 7(2), 93-102.

Erickson, M. & Jacobsen, R. On computer applications and statistics in sociology, toward the passing away of an antiquated technology. Teaching Sociology, 1973, 1(1), 84-102.

Evans, D. A. Computers in the teaching of statistics. Journal of the Royal Statistical Society, 1973, 136, Part 2, 153-190.

Fachnie, J. & Schillace, R. Attitudinal effects as a function of undergraduate statistics course design: Personalized (self-directed) vs. traditional. Higher Education, 1973, 2(1), 73-80.

Finn, J. D. Updating instruction in statistics. Paper presented at American Educational Research Association, New York, February, 1971. (ERIC ED 047 984)

Freund, J. E. Modern elementary statistics, 3rd ed. New York: Prentice-Hall, Inc. 1967.

Forsythe, A. & Bleich, D. Some experiences using computers to assist in the teaching of basic statistics. International Statistical Review, 1973, 11(2), 245.

Golub, G. H. Matrix decompositions and statistical calculations. In Statistical Computations (Milton, R. & Nelder, J., eds.), pp. 365-397. New York: Academic Press, 1969.

Harris, G., Swanson, J. & Duerr, J. OMNISHRIMP: An interpretive language which mimics OMNITAB. Behavior Research Methods & Instrumentation, 1974, 6, 200-204.

Hodges, J., Krech, D. & Crutchfield, R. An empirical introduction to statistics: Statlab. New York: McGraw-Hill Book Co., 1975.

Hoel, P. Elementary statistics, 2nd ed. New York: John Wiley & Sons, Inc, 1966.

Houchard, R. & Meagher, J. STP: Statistical package. Michigan: Western Michigan University Computing Center, 1974.

Howze, G. R. Use of computer time-sharing to individualize instruction in a course in elementary statistics. Social Science Information, 1973, 12(6), 149-157.

Huntsberger, D. Elements of statistical inference. New York: Allyn and Bacon, Inc., 1967.

Kanji, G. K. The role of the statistical laboratory in the teaching of statistics. International Journal of Mathematics & Science Technology, 1974, 5, 53-57.

Keller, F. S. Good-bye teacher ... . Journal of Applied Behavior Analysis, 1968, 1, 79-89.

Kirch, A. M. Introductory statistics with FORTRAN. New York: Holt, Rinehart, & Winston Inc., 1973.

Koh, Y. O. TUSTAT-II and STRAP-II. Personal correspondence. Computing Center, University of Nevada System, Reno, Nevada 89507.

Kossack, C. & Henschke, C. Introduction to statistics & computer programming. San Francisco: Holden-Day Inc., 1975.

Kshirsagar, A. M. Multivariate analysis. New York: Marul Dekker, Inc., 1972.

Lehman, R. Computer generates data for statistics. Journal of College Science Teaching, 197 , 4, 48.

LeKan, H. (ed.). Index to computer assisted instruction. New York: Harcourt Brace Jovanovich, Inc., 1971.

Li, J. C. R. Statistical inference I. Ann Arbor: Edwards Brothers, Inc., 1968.

Lohnes, P. & Cooley, W. Introduction to statistical procedures with computer exercises. New York: Wiley, 1968.

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

McCabe, G. P. Book review of "Introductory statistics with FORTRAN, by Kirch". Journal of the American Statistical Association, 1974, 69(348), 1045.

Mendenhall, W. Introduction to probability and statistics, 3rd ed. New York: Wadsworth Publishing Co., 1971.

Michael, E. S. Teaching statistics, while simultaneously saving, time, chalk, etc. ... . Paper presented at the Conference on Computers in the Undergraduate Curricula, Claremont, California, June, 1973. (ERIC ED 079 993).

Morris, C. N. & Rolph, J. E. Introduction to statistics and data analysis with computer applications - I & II. Santa Monical, California: Rand Publications, September, 1971. Order #P-4695 & P-4696.

Nie, N., Bent, D. & Hull, C. Statistical package for the social sciences. New York: McGraw-Hill, 1970.

Rao, C.R. Generalized inverses for matrices and its applications in mathematical statistics. In Research papers in statistics (F. David, ed.). New York: Wiley, 1966.

Rattenbury, J. & Pelletier, P. Data processing in the social sciences with OSIRIS. Monograph published by Institute for Social Research. Ann Arbor: University of Michigan, 1974.

Ryan, T. & Joiner, B. MINITAB: A statistical computing system for students and researchers. The American Statistician, 1973, 27, 222-225.

Salmon, P. & Tracy, R. Computer-generated computation exercises. Behavior Research Methods & Instrumentation, 1975, 7(3), 307.

Skavaril, R. V. Computer-based instruction of introductory statistics. Journal of Computer Based Instruction, 1974, 1(1), 32-40.

Spirer, H. Mini-simulation--A remote computer terminal teaching aid for statistics. Journal of Business Education, 1972, 47(5), 206-207.

Swanson, J., Ledlow, A., & Harris, S. Using OMNITAB interactively in a statistics laboratory. Behavior Research Methods & Instrumentation, 1973, 5, 199-204.

Tanis, E. A. A computer laboratory for mathematical probability and statistics. Paper presented at the Conference on Computers in the Undergraduate Curricula, Claremont, California, June, 1973. (ERIC ED 079 985)

Thomas, D. B. STATSIM: Exercises in statistics. Office of Naval research report AD-723-856. Springfield, Virginia: National Technical Information Service, 1971. (ERIC ED 055 440)

Thomas, W. H. The development of a statistical experiment simulator: Final report. DHEW report BR-7-0581. (ERIC ED 063 804)

Tira, D. An introduction to the theory and application of the product-moment family of correlation via a computer assisted instruction system. Unpublished Masters thesis, Ohio State University, 1970. (ERIC ED 052 627)

Wagner, G. & Motazed, B. The proctorial system of instruction combined with computer pedagogy for teaching applied statistics. American Statistician, 1972, 26(3), 36-39.

Wallace, D. L. Computers in the teaching of statistics: Where are the main effects. In Statistical Computations (Milton, R. & Nelder J., eds.). New York: Academic Press, 1969.

Wassertheil, S. Computer assistance in statistics. Improving College and University Teaching, 1969, 17(4), 264-266.

Wegman, E.J. Computer graphics in undergraduate statistics. International Journal of Mathematics Education and Science Technology, 1974, 5, 15-23.

Wegman, E.J. & Gere, B.H. Some thoughts on computers and introductory statistics. International Journal of Mathematics Education and Science Technology, 1972, 3, 211-221.

White, D. Statistics for education: With data processing. New York: Harper & Row, 1973.

Wolf, R. Book review of "Statistics for education: with data processing by D. White". American Educational Research, 1974, 11(4), 435.

Veldman, D. J. FORTRAN programming for the behavioral sciences. New York: Holt, Rinehart, and Winston Inc., 1967.

Exercise 5.1

Statement of the Problem. Prepare and execute a program that will take a random sample of n observations from a population which is N(10,100). Let us pretend that the population mean is unknown. Using the 5% confidence coefficient, compute two confidence intervals for μ (the population mean). In the first, compute the confidence interval assuming σ^2 is known, and in the second, compute the confidence interval assuming σ^2 is unknown, that is, just replace σ^2 by the sample variance. Repeat the above experiment N times. Tabulate the number of times the population mean $\mu = 10$ falls within the calculated intervals.

Input. Test your program with the following sets of input values.

Data Set 1	*Data Set 2*
n = 10	n = 40
N = 100	N = 100

Output. Your program should output the number of times the population mean μ falls within the calculated intervals, the sample mean and variance for each of the N experiments, and the total sample mean and variance.

Discussion and Questions. The purpose of this exercise is threefold. First, the exercise is to show that in repeated sampling, the population mean will fall in 95% = (100 - 5)% of the calculated 5% confidence intervals. Second, when the population variance is unknown and when the sample size is large, we can rely heavily on the high degree of probability (confidence coefficient) established prior to the running of the experiment. Third, as the sample size increases within each experiment, the better are the point estimates $\bar{x}$ and s^2 of μ and σ^2, respectively. As a guideline, n should be greater than 30 for this approximation to be valid.

1. For each data set and σ^2 known, how does the tabulated number of times the population mean μ falls within the calculated interval compare with the theoretical result, that is, N X .95?
2. For each data set and σ^2 unknown, how does the tabulated number of times the population mean μ falls within the calculated interval compare with the theoretical result, that is, N X .95?
3. How do the answers to Questions 1 and 2 compare? What is the consequence of increasing the sample size without changing the confidence coefficient?
4. What would be the effect if we reduced the confidence coefficient to 1%?
5. What is the consequence of using zero percent confidence coefficient?
6. What is the advantage of having a large sample in determining the confidence interval of a population mean? Illustrate your answer with the output of your computer experiment.
7. Why do the lengths of the confidence intervals of a population mean change from sample to sample even if the sample size remains the same?
8. Regardless of the sample size, one can obtain a confidence interval. Why does one prefer a large sample? Comment about your point estimates of μ and σ^2.

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1. 29 modules of computer assisted instruction in a course named 'gen650'.
2. 9 types of exercise-generating programs.
3. 21 CPS analysis programs.
4. Various programs supplied by the central administration of the University.

Computer Assisted Instruction Modules

Each of the 29 computer assisted instruction modules has been given a name which is the program label used by the students to access the module. The labels used and a brief description of the computer assisted instruction modules are shown in Table 1.

Table 1. Computer Assisted Instruction Modules

LABEL	CAI UNIT	LABEL	CAI UNIT
regsta	Preliminary instruction on some CAI system features: signal for student response, use of the go to command, use of the calc feature, comments to the author, and the notational system used in the course.	**civar**	Confidence intervals for the variance of a normal distribution by means of the chi-square distribution.
normds	The normal distribution and the parameters a3 and a4.	**fdist**	F distribution and test of the equality of two population variances.
stnmds	The standard normal distribution.	**apsta**	Unpaired t tests. Test of the hypothesis that the means of two populations are equal.
revb	Review of some topics needed before taking a unit on the Central Limit Theorem.	**ptt**	Paired t tests. Test of the hypothesis that two population means are equal based on paired observations.
clt	Central Limit Theorem.	**anova1**	One-way analysis of variance.
i	Quiz concerning some aspects of Central Limit Theorem – some practice problems.	**pbsowa**	Practice problems and review questions concerning the one-way analysis of variance.
splst	Review on population parameters and a unit on sample statistics as calculated in Laboratory Problem Set 1.	**coding**	Effects of coding operations on sample mean and sample variance.
dea	Hypothesis testing with special reference to decisions and their outcomes, Type I and Type II errors.	**expval**	Expected values through the one-way analysis of variance and including practice problems.
ztest	Test of null hypothesis that mean of a normal distribution equals some specified value by means of the Z test.	**anova2**	Two-way analysis of variance.
tdist	Use of t distribution to test the hypothesis that population mean equals some specified value.	**reg**	Single variable, linear regression.
cimu	Confidence intervals for the mean of a normal population by means of the t distribution.	**regqus**	Practice problems and review questions on the topic of single variable, linear regression.
cimuex	Some practice problems involving the use of the t distribution to calculate confidence intervals for the mean of a normal population.	**cor**	Correlation.
chisq	The chi-square distribution.	**meansp**	Mean separation procedures. Least Significant Difference and Duncan's Multiple Range.
chivar	The use of the chi-square distribution to test the null hypothesis that the variance of a normal distribution equals some specified value.	**beta**	Probability of Type II errors in Z test of H_0: $\mu = \mu_0$.
		reldis	Relationships between theoretical distributions (Z, t, chi-square, and F distributions).

Table 2. Exercise Generating Programs

Program Name	Description
LP1B	Finite populations.
LP1A	Exercises concerning the normal distribution.
LP1	Single sample statistics and analyses, descriptive statistics involving sample mean and sample variance, tests of hypotheses about mean and variance. This program also produces a data base used for the analysis of variance exercises.
LP19B	One-way analysis of variance, equal replication.
LP20A	One-way analysis of variance, unequal replication.
LP21B	Two-way analysis of variance, single observation per cell.
LP18	Linear regression.
LP11A	Least Significant Difference.
LP11B	Duncan's Multiple Range.

Table 3. Statistical Analysis Programs

Program Name	Description
LP1.1	Items (1) through (10) in Laboratory Problem Set 1, sample statistics.
P2.1	Sample mean and related statistics.
P1.1	All of Laboratory Problem Set 1B, calculation of population parameters.
P3.1	Laboratory Problem Set 1A, probabilities for normal variates.
P4A.1	Test of $H_0 : \mu = \mu_0$.
P4B.1	Confidence intervals for μ. Input data include all the observations in a sample.
P4B.12	Confidence intervals for μ. Input data are sample mean, standard error, and t value. This program may be used to compute Items (13) through (16) in Laboratory Problem Set 1.
P5.1	Test of equality of two population variances by F test.
P6A.1	Test of the difference between two population means by t test for unpaired observations.
P6B.1	Test of the difference between two population means by t test for paired observations.
P7A.1	Confidence interval for σ^2. Input data include all the observations in a sample.
P7A.12	Confidence intervals for σ^2. Input data are corrected sum of squares and the two chi-square values. This program may be used to compute Items (17) through (20) in Laboratory Problem Set 1.
P7C.1	Analysis of a 2 x 2 contingency table.
CODING	This program may be used to code a set of variates, $X_1, ..., X_i, ..., X_n$ to $Y_1, ..., Y_i, ..., Y_n$ by the operation $$Y_i = AX_i + B$$ in which A and B are constants. This program may be used to produce the coded data for LP19C and LP19E.
P8.1	One-way analysis of variance. This program may be used for Laboratory Problem Sets 19B, 19C, 19D, 19E, and 20A.
P9A.1	Linear regression. The data are entered in "bivariate form," that is, $(X_1, Y_1), ..., (X_i, Y_i), ..., (X_n, Y_n)$.
P9A.12	Linear regression and test for linearity. This program can be used for LP18B. The data are entered in "array form," that is, $n_1, X_1, Y_{11}, ..., Y_{1n_1}, ..., n_k X_k Y_{k1}, ..., Y_{kn_k}$.
P9B.1	Correlation.
P10.1	Two-way analysis of variance. This program can be used for Laboratory Problem Set 21B.
P11A.1	Least Significant Difference. This program can be used for Laboratory Problem Set 11A.
P11B.1	Duncan's Multiple Range. This program can be used for Laboratory Problem Set 11B.