COMPUTERS IN TEACHING

1979 State of the Art Report of Instructional Computing

Mathematics and Statistics

Herbert L. Dershem, Hope College
CONDUIT Series Editor for Statistics

David A. Smith, Duke University
CONDUIT Series Editor for Mathematics

CONDUIT

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1. Introduction

This report is primarily concerned with the nontraditional use of computers in undergraduate courses in mathematics and statistics. For reasons explained below, we make only passing mention of traditional computer use in courses in numerical analysis, computer science, programming, operations research, and other areas for which computing is essentially mandatory.

Except for statistics courses, the dominant computer activities in the courses under consideration are problem-solving, simulation, and learning to program. (A great deal of programming instruction goes on in lower-division mathematics courses not explicitly labeled as programming courses.) In statistics courses, the dominant activities are data analysis and problem-solving (much of the latter presumably dependent on the former). Most of this computing is being done on large- to medium-size machines in an interactive, time-sharing mode with programs written in BASIC or FORTRAN.

In the recent past, the number of computer users among mathematics faculties has increased significantly. Receptiveness to the use of computers in traditionally computerless courses has increased even more, but a number of barriers have prevented translating this heightened interest into actual use: obsolete or awkward hardware and software; a budgetary crunch that prevents keeping up with new developments, even when costs are declining; lack of time for developing new materials and lack of reward for those who take the time; and perceived lack of class time for adding anything to existing courses. (Subtracting anything is seldom considered.) Then there are barriers that are never mentioned on survey forms, such as ego damage suffered by an instructor who finds that his or her own training is inadequate or outmoded and fears (correctly) that students will pick up computing faster than he or she.

In contrast to the situation only a few years ago, there are now effective, transferable materials to support computer use in a wide range of mathematics and statistics courses, and the process of producing such materials has become more rational and sophisticated. However, awareness of these materials on the part of the faculty using computers remains very low, as evidenced by the fact that most of them continue to prepare their own materials.

Given the fact that the level of use is not anywhere near saturation (of potential use, not of existing facilities), one can confidently predict continued increase of use, subject to the same constraints that have operated in the recent past, especially budgetary constraints. Awareness of materials will continue to grow, due to modest marketing efforts, conferences, and reports in journals that are not specifically computer-oriented. Microcomputers will have an effect, especially where departments can find a way to acquire them as office equipment or word processors, but relatively few mathematicians are presently aware of their potential.

The more innovative and sophisticated developments in technology and courseware have had little impact on the vast majority of campuses, and that will continue to be the case, especially where computing facilities are oriented toward administrative or research needs, or worse yet, nonexistent. But there are many bright spots on the horizon suggesting an imminent dawning and a sunny tomorrow, with the simultaneous emergence of inexpensive, easy-to-use, and effective hardware and transferable software, and of heightened interest on the part of the mathematics faculty.

2. Background and Current Patterns

The decade of the sixties was a time of revolution in the mathematics curriculum of primary and secondary schools. Concurrent with these changes was a quieter reorganization of the curriculum in colleges and universities. The most effective voice for change in the college mathematics curriculum in the past 15 years has been the Committee on the Undergraduate Program in Mathematics (CUPM) of the Mathematical Association of America. This committee was charged with the responsibility for making recommendations for the improvement of college and university mathematics curricula at all levels and in all educational areas. This group issued periodic reports on various areas of concern, including a 1965 report entitled A General Curriculum in Mathematics for Colleges. This report, which had widespread and extensive influence on the mathematics programs in the U.S. colleges and universities, undertook to identify a central curriculum, beginning with calculus, that would serve the basic needs of those desiring an undergraduate education in mathematics. Many colleges revised their course offerings in directions suggested by this report. Although the presence of computers was being felt in the curricula of other disciplines, this 1965 CUPM report did not address itself to the relationship of the computer to education in mathematics.

Apparently it was the view of experienced teachers and researchers in 1965 that the computer had little to contribute to the classroom. Nevertheless, scores of individuals were experimenting with the computer to augment instruction in mathematics, primarily in statistics and calculus. During this period, the National Science Foundation, through its Office of Computing Activities, played a major role in promoting the development and use of computer-based instructional materials in mathematics by funding computer-oriented curricular projects, summer institutes in computing and mathematics for college teachers, and a number of large curriculum development projects of which mathematics was a part.

The number of apparently successful trials of computer-based instructional materials is now fairly large, and CUPM has since published two reports dealing with mathematics instruction and computing. The first of these reports, Recommendations for an Undergraduate Program in Computational Mathematics (CUPM, 1971), proposed a new academic major in the mathematical sciences that combines courses in mathematics, computer science, and computational mathematics. This suggestion grew out of the committee's basic recommendation that "mathematics departments should experiment with innovative undergraduate mathematics programs which emphasize the constructive and algorithmic aspects of mathematics, and which acquaint students with computers and with the uses of mathematics in computer applications." The second report, Recommendations on Undergraduate Mathematics Courses Involving Computing (CUPM, 1972), recognized the potential influence of the computer on the basic undergraduate courses in mathematics, and proposed changes in certain traditional courses, as well as the introduction of some new courses designed to take advantage of the computer.

Perhaps the first substantial sign of growing acceptance of these ideas was the symposium on "The Influence of Computing on Mathematical Research and Education", jointly sponsored by the American Mathematical Society and the Mathematical Association of America in connection with their annual summer meetings in 1976 in Missoula, Montana. Subsequent national and regional meetings of both AMS and MAA have included a variety of speakers, panels, and special sessions on computer-related topics, including the use of computers in undergraduate courses.

A more recent stimulus to growth in this type of computer use is the report of a National Research Council committee (AMTRAC) on the role of applications in the undergraduate mathematics curriculum. This report may stimulate the CUPM-type efforts of the 1980's, although it is considerably less detailed than any of the CUPM documents. Among its many recommendations is the following:

> [We recommend] "that every mathematics major acquire early in his or her college career a basic competence in computer programming so that he or she can design algorithms and write programs of some complexity. This competence may often best be gained by requiring a course in computer science; where this option is used, the required course should be designed so that many of the examples and exercises relate to the material of the student's mathematics courses. Further, [we recommend] that, to the extent possible, the student's computing knowledge be utilized in appropriate mathematics courses."

An additional factor bearing on the trend in curriculum change (not neglected in the AMTRAC report) is the changing employment picture for mathematicians. There is now a clear recognition that a mathematician whose training is exclusively theoretical and abstract is not as employable as he or she was in former years. As a consequence, college teachers are now more receptive to changes in the curriculum that would provide for different avenues of education within the mathematical sciences, especially programs that educate in the applications of mathematics to other disciplines, or programs that offer a computer science emphasis. Thus, there is now a favorable climate for the introduction of computer-oriented instruction into the curriculum on a broad scale.

Some of the early experiments with computer materials for the mathematics classroom have matured into publications (not necessarily of the traditional textbook type) and are listed in our bibliography below. Others have run their course and died, including some very ambitious and briefly successful ones, such as CRICISAM. It is still the case that most of the supplementary materials for traditional courses never leave the site of origin, but it is now possible to find good materials in some transferable form across a broad range of the standard courses. (This was not the case only a few years ago.) Nevertheless, a majority of the mathematics instructors willing or eager to use computers are still writing their own materials, in some cases due to their ignorance of available materials.

There are several reasons for this gap of information about materials. (1) The large-scale, nonprofit, grant-supported projects have usually not been funded for massive advertising and marketing efforts. (2) Commercial publishers have been ambivalent about investing in computer-related materials. On the one hand, they would like to be one jump ahead of the competition with newly emerging and potentially profitable materials; on the other hand, their conservative practices cause them not to publish in new areas unless they get rave reviews and to stop advertising anything that doesn't show a profit very quickly. (Rave reviews and quick profits are almost incompatible with published materials in newly emerging areas due to the conservative practices of educators when it comes to curriculum change.) (3) Finally, the widely read journals are just now catching up with computer-induced changes in the curriculum.

Computer-wise innovators are now developing materials that depend on and benefit from new technological developments: microcomputers, graphics devices, voice synthesizers, and so on. At the same time, large numbers of mathematics teachers are just beginning to learn about their first computer, which is likely to be small, shared with many users, and capable of communicating only via punched cards or teletypes. As we predicted in our previous report, many schools are locked in to obsolete computing systems by a budget crunch that does not even permit spending a few thousand dollars for a modest microcomputer system (although some instructors are buying their own and sharing with their students). There are probably many fewer campuses now with no computer system at all, but the technological and developmental gap between the "haves" and the "have-nots" of the computer world is actually widening.

3. Examples of the Use of Computer in Mathematics

We list here some of the ways computing is being used in mathematics and statistics courses. This list is not exhaustive and the examples are not necessarily the best of their type. Some are represented by published materials and/or transferable software, and others exist only at the site of origin at the present time. Where materials are available, these are listed in the bibliography.

Problem-Solving

Problem-solving is the dominant mode of computing in mathematics courses, and examples may be found throughout the materials listed in the bibliography. We will cite only one example of a use that was rare a few years ago and is becoming standard in an otherwise conventional course. There is a growing consensus that the standard undergraduate course in ordinary differential equations should introduce the student to numerical as well as analytic methods of solution. While most instructors do not spend a great deal of time on this (many still view the whole idea with a great deal of suspicion), new differential equations texts (for example, Hagin) contain some material on numerical methods that may range from a simple discussion of Euler's method up to fourth-order Runge-Kutta and predictor-corrector methods. For those using texts lacking this material or not going far enough with it, there are now good supplementary materials available (for example, Van Iwaarden).

Illustration of Concepts

It is now routine to actually evaluate Riemann sums when the integral is first introduced in the calculus course. This is a much more useful way to illustrate the concept than the traditional, but clumsy, digression to cover formulas for sums of integer powers, which leads to the worst possible way to find the area of a triangle. Simple Riemann sums can be evaluated using a calculator, but more complicated ones become tedious because of the function evaluations. Thus, access to even a small computer is very helpful in keeping the calculations from getting in the way of understanding the integral as a number.

Another example of concept reinforcement in calculus is the observation that the location of roots by interval-halving is also a constructive proof of the Intermediate Value Theorem (see Smith's Interface).

Statistical Packages

Two approaches to the implementation of statistical packages are illustrated by the Tanis package and by Minitab. The Tanis package consists of a set of FORTRAN subroutines and an accompanying laboratory manual containing exercises the student can carry out on the computer through the use of the subroutines. The exercises are intended for use in a mathematical probability and statistics course at the junior-senior level. The computer is used in these exercises as a tool to simulate random experiments and to produce computational graphical analyses of the results. The subroutines are written to be used in either a batch or an interactive environment with student-written programs that call them.

In contrast, the Minitab approach is to provide the student with a separate language to generate, analyze, and display statistical data. An accompanying handbook is provided that introduces the features of the language and contains exercises making use of simulation, plots, and techniques to illustrate statistical concepts and data exploration methodology. Like the Tanis package, Minitab is written in FORTRAN and is available in both batch and interactive modes. Minitab, however, requires no prior programming knowledge or computer experience on the part of the student.

Data Analysis

The three most commonly used data analysis packages are SPSS, SAS, and BMDP. Each of these packages consists of a set of routines for data entry, data management, and statistical analysis. Each also provides its own language and a user's manual. The manuals present the syntax of the languages and descriptions of the procedures that are implemented.

Computer-Assisted Instruction

In proportion to the time and effort expended in mimicking techniques successful in other fields, computer-assisted instruction (CAI) in college-level math has not become common. One reason has been the limitations of physical facilities: teletype-like devices with low transmission speeds and limited character sets are not well suited to communicating mathematics. Another reason is that the concepts encountered in courses beginning with calculus are not easily taught or learned by rote drill techniques, although these may be very effective for acquiring necessary computational skills. A good example of useful CAI materials at the precalculus level is the package developed recently at the University of

Tennessee at Chattanooga by Richard Detmer and Clinton Smullen for drill and practice in various topics in algebra, including word problems. An example of materials being developed at the calculus level is the package (not yet available) by Frank Anger and Rita Rodriguez of the University of Puerto Rico. (Their programs are in BASIC for an HP 2000/Access system with text presented to the student in Spanish. The program's REMark statements are in English, however.)

A number of systems have been designed for the development of CAI materials in mathematics. In this approach, the focus is on moving the development system rather than the finished materials. Descriptions of the following examples may be found in the CCUC/9 Proceedings: MATHDOC (Mark Christensen, Georgia Tech), and QuATE (Doug Aims, Palo Alto School District, California).

CAI/CATC

Detmer and Smullen have also developed a simple but useful CMI system for their algebra course in which students are self-paced. With this system, only the instructor or lab manager actually uses the computer. Mastery tests are generated by the computer and kept on file. Students request tests or re-tests whenever they are ready, and the tests are graded immediately by a lab assistant using a computer-prepared answer key. All record-keeping and pacing of the students' progress is handled by on-line data files.

A similar system has been described by W.J. Smolinski of the University of New Brunswick in ERM 10 (1978, pp. 56-63). This system was designed for an electrical engineering course, but would be adaptable to any quantitative course. The principal difference between this package and the Detmer-Smullen system is that the tests are generated on-line when the student requests one at the terminal. The instructor identifies certain parameters in the problems that are to be determined by the computer, thus individualizing the test. The test is printed for the student at a hard-copy terminal. Numerical answers are identified by parameters, and when the test is finished, the student re-enters the computer program and enters his numerical answers at the terminal. Grading and record-keeping are then done by the computer.

Computer-assisted test construction (CATC) can be very useful even if the course is not self-paced and not computer-managed. For example, Mark Hale (University of Florida) has developed a problem generator for differential equations.

Graphics

While graphics equipment is not yet available on most college campuses, many experiments are under way to exploit this medium for the obviously visual aspects of many mathematics courses. These projects are much too diverse and system-dependent to categorize neatly or summarize briefly, but most involve a "super blackboard" approach, some also incorporating motion. For examples, see the papers by Gerry Porter (University of Pennsylvania) and Elliot Tanis (Hope College) in the NECC/79 Proceedings.

Another approach that has been tried is to use computer graphics to design and produce static materials (for example, customized overhead transparencies or handouts). See the paper by K. Joy, J.R. Warner, and R. Yuskaitis in the CCUC/8 Proceedings for an example.

Finally, while waiting for the graphics equipment to arrive, character graphics (line-printer or low-speed terminal) is a feeble but useful substitute. Every computer system has programs available for character plots of simple functions. For an example of three-dimensional character graphing, see Smith's Surface package.

Networking

The primary networking service supporting college-level education is EDUNET. A node of this network provides access by local phone call to many large, sophisticated computer systems and a lot of packaged software. For example, Shapiro's ISCI materials are available from the University of Minnesota via EDUNET. Statistics packages such as SAS and SPSS are available from a number of suppliers. The network also provides a way to examine materials, such as those from CONDUIT, before deciding to purchase them.

There are some risks and frustrations associated with using a remote system, although EDUNET is doing everything possible to assure that help is available. One of its early offerings was the MACSYMA symbolic manipulation system from MIT, a very powerful tool for advanced mathematics and applications. Unfortunately, the version MIT offered was problematic and not maintained. EDUNET has since withdrawn this service, but there is some prospect that a supported version of MACSYMA will become available on EDUNET in 1980. (A good version of MACSYMA is available via ARPANET for those institutions that qualify, or by long distance phone call to MIT, prohibitively expensive for most potential users.)

Word Processing

The primary obstacle to computer-based text editing in mathematics has been the limited capability of typewriter-like devices for producing acceptable mathematical formulas and symbols. Now it is becoming possible, with dot matrix devices and programmable keys, to overcome this difficulty. Barry MacKichan and Roger Hunter (New Mexico State University) are using Pascal on a Terak computer to develop a mathematical text processor that will make it possible to write and edit papers, lecture notes, and so forth, with the proper mathematical spacing and characters.

4. Summary of Survey Results

As was the case with the 1978-79 CONDUIT surveys in other disciplines, the mathematics/statistics survey was in three parts: department, faculty, and course. The survey forms were sent to department heads requesting that they fill out and return the departmental forms and pass on to appropriate faculty members the combined faculty/course forms. The latter forms were also sent directly to approximately 100 faculty members known to be actively using computers in instruction. In all, 800 departmental forms and 961 faculty forms reporting on 2,050 individual courses were returned.

Departmental Profiles

Most of our returns are from departments with Mathematics or Mathematical Sciences in their titles. The few from departments of statistics and/or computer science are all from large schools. Some demographic characteristics of these departments are shown in table 1.

Fifty-four percent of the department heads responding reported increased use of the computer in their departments over the past two years, 43 percent reported no change, and only three percent reported a decline. Three out of four expect to see increased use over the next two years, and less than one percent foresee a decrease.

Where there has been an increase in use, the dominant reasons have been demand by students and faculty, and changes in the computer system. The factors limiting use (and growth of use) are seen to be lack of funds and lack of equipment. These factors are most important in smaller schools and in schools where there is little or no use now. (But most of the schools where all or nearly all of the faculty use the computer are also small.) Lack of funds is also the major reason cited by those who see no future growth, while equipment changes and increased interest are expected to be the driving forces by those who do see growth.

Past increases tend to be concentrated in the four-year colleges and universities, and stagnation is concentrated in the schools that do not offer a bachelor's degree. Future growth appears to be most likely in departments that offer a bachelor's or master's as their highest degree, much less likely in the departments granting Ph.D.'s and in the junior colleges.

Less than two percent of department heads identified micros as a source for future change, but to a person these respondents expected increased computer use.

TABLE 1

Departmental Demographic Profile

Category	Response	Percent
Highest degree	None	4
	Associate	32
	Bachelor's	39
	Master's	13
	Doctorate	11
School enrollment	1-1,000	26
	1,001-5,000	41
	5,001-15,000	20
	> 15,000	13
Department enrollment	1-10	23
	11-100	24
	101-500	26
	501-900	9
	> 900	18
FTE faculty	1-5	37
	6-10	27
	11-20	20
	> 20	16
Number of faculty using computers	0	25
	1	19
	2	18
	3	13
	4 or more	25
Extent of use	None	23
	Infrequent	32
	Moderate	39
	Extensive	7

Faculty Profiles

Characteristics of our 961 faculty respondents are shown in table 2. Of those faculty members answering questions about change, 66 percent reported increased use in the past two years, 30 percent reported no change, and only four percent reported decreased use. Seventy-three percent of these respondents see further increased use in the next two years, 26 percent see no change, and only one percent predict a decrease. Where there has been a decrease or no change, the limiting factors were lack of money and lack of support staff. Where a decrease or no change is expected in the future, the reasons most often cited were saturation of facilities and/or interest. The primary reasons for increased use in the recent past were: course changes, hardware, software, student demand, and growth in the field, in that order. For future increases, the driving forces appear to be hardware, software, student demand, growth in the field, and the number of students. (These factors are rated in a somewhat different order by faculty in departments of statistics, where hardware is seen as a much less important matter and software as more important.) The most important factors limiting growth in computer use are

TABLE 2

Faculty Demographic Profile

Category	Response	Percent
Type of school	Two-year	19
	Four-year	41
	University	40
School enrollment	1-1,000	16
	1,001-5,000	39
	5,001-15,000	30
	> 15,000	13
	No response	3
Academic rank	Instructor	12
	Asst. Professor	27
	Assoc. Professor	32
	Professor/Chair	24
	Other	5
Number of courses with computing	0	7
	1	29
	2	25
	3	20
	4 or more	18

seen to be: lack of time, equipment (not so important to statisticians), funds, software, support, training of students (more important to statisticians), and academic rewards, in that order. Over half the respondents mentioned lack of time, and just under one-fourth mentioned lack of reward.

We will see in the next section that use of published materials, except in the categories of programming, numerical analysis, and computer science, is still at a very low level. When asked what materials needed to be developed, the order of responses was: problem-solving, simulation, programming exercises, drill and practice, tutorial, and data analysis. For those in statistics departments, the order was quite different. Over three-fourths cited data analysis, while simulation and problem-solving were a distant second and third, and none of the other categories received substantial support. It is worth noting here that only a third of the respondents (a fifth in the case of statisticians) were aware of the existence of CONDUIT, and only six percent had used any CONDUIT materials. It will be clear from the bibliography that many of the materials "needed" already exist (CONDUIT's and others). However, it is not clear whether our respondents were really expressing perceptions of need or just of their own patterns of use.

Course Profiles

A breakdown of the 2,050 individual courses reported is shown in table 3. Mathematics here means everything not included in the other categories.

TABLE 3

Course Breakdown

Category	Number	Percent	Published Materials
Mathematics	720	35	77
Statistics	293	14	67
Computer Science	257	13	156
Numerical Analysis	228	11	104
Programming	401	20	411
Other (unidentified)	151	7	3

Several observations about table 3 are in order. First, over 40 percent of the courses reported are in the areas of computer science, computer programming, and numerical analysis, where computer use is not only mandatory but essentially well-established, well-understood, and well-supported by text materials. In schools that are large enough to have a separate computer science department, these subjects are normally among its listings (placement of numerical analysis is subject to local politics), but in most schools they are still taught in the mathematics department, if at all. CONDUIT has never assumed any responsibility for distribution of materials in these areas, because none seemed to be needed. Our emphasis has been, and continues to be, on traditional mathematics and statistics courses in which use of a computer is still a relatively new idea. Thus, except for a brief comment about the materials in use in computer science courses, we will focus on the first two categories in table 3. A further breakdown of the mathematics courses into traditional categories is shown in table 4.

TABLE 4

Mathematics Courses Using Computers

Course Title	Number	Percent	Published Materials
Calculus (single-variable)	194	27	24
Linear Algebra	77	11	11
Differential Equations	69	10	9
Liberal Arts Mathematics	69	10	4
Precalculus	68	9	4
Finite Mathematics	46	6	4
Calculus (multivariable)	32	4	
Operations Research	30	4	12
Mathematical Modeling	29	4	2
Linear Programming	24	3	3
Teacher Education	20	3	
Engineering Mathematics	16	2	
Number Theory	13	2	2
Business Mathematics	11	2	1
Probability	7	1	1
Abstract Algebra	6	1	
Geometry/Topology	4	1	
Advanced Calculus	3	-	
Symbolic Logic	2	-	
Totals	720	100	77

The following patterns of computer use and materials emerged from the course survey. As noted already, for most courses the only computer-related text used (if any at all) was a book on programming. About 50 percent of the respondents reported using their own prepared notes, another six percent somebody else's notes. The prevailing types of student activities were problem-solving, then simulation and learning to program (these two about even), then drill and data analysis (also about even). The primary activity for instructors, if they used the computer at all, was demonstrations.

Most computing in this field is being done on large mainframes and on minicomputers, with the mainframes holding a slight edge (not as large an edge as for all disciplines surveyed). Of course, the mainframes serve more users and tend to be located at the larger schools, so many more students are using large computers than small ones. The use of both microcomputers and programmable calculators is still very small in mathematics courses. The dominant mode of use for both maxis and minis is interactive, with 65 percent reporting use of hard-copy terminals and 58 percent reporting CRT terminals. Only 29 percent report use of batch processing (punched cards and line printers) and 17 percent report using graphics display terminals. Of course, the batch processing is being done largely on mainframes and with larger numbers of students per course. The language used most often is BASIC, by almost a two to one margin over FORTRAN, with all other languages far behind. The most popular of the other languages is APL, and it is used by less than 10 percent. APL and Pascal are in use primarily at schools with less than 10,000 students, and PL/I is found primarily at schools with more than 10,000. As with large computers and batch processing, the use of FORTRAN is understated in terms of number of students, because it too is associated with larger numbers per course.

The level of computing activity by students is greatest for freshmen (nearly half of the courses reported are at the freshman level) and declines rapidly with the upper-level classes. The use of problem-solving also declines with student advancement, and simulation takes over as the dominant mode in the junior and senior years. Tutorials, drills, and learning to program are activities that are heavily concentrated in the freshman year, as one would expect. These patterns of student use are the same regardless of the size of the school, but class size has a definite bearing: simulations are somewhat more likely with smaller classes, and tutorials and drills somewhat more likely with larger classes.

Demonstration, the topranking type of instructor activity, cuts across differences of school type and size, level of course, computer type, and language used. However, demonstrations are less likely to occur with class sizes over 100, for obvious reasons. (The technology exists for large-scale demonstrations, but it would be expensive to equip every classroom.) Other instructor activities, such as instructional management, test generation, and test scoring, are concentrated at the freshman level, with large class sizes, and on mainframes with FORTRAN as the operating language.

Class sizes for the reported courses showed about one-fourth in each of the ranges 6-15, 16-25, and 26-50, and half the remainder with five or less, and half over 50. Almost 70 percent of these courses were one semester or one quarter, and most of the rest not over one year. For 80 percent of the courses, the computer supported not more than 20 percent of the student's time. However, the ratio of required to optional computer use was almost two to one.

Computer Use in Statistics

Computer use in statistics courses is quite common. The predominant application is the use of the computer as a computational tool to allow the student to avoid tedious, time-consuming calculations and to permit the analysis of large, interesting data sets. This widespread application is indicated in the survey by the fact that 86 percent of the statistics courses using the computer involve data analysis as a student activity, and 74 percent involve problem-solving. In fact, many courses have been introduced at the upper undergraduate level that are devoted entirely to the use of the computer as a tool in data analysis. The pattern of computer use in statistics courses differs according to the size of the school. At smaller colleges the faculty tend to use locally written software or a package provided by the computer vendor. At the larger universities one or more of the commercially marketed data analysis packages are available and are used by the students.

The survey results indicate that there is approximately equal usage of the three most popular packages, Minitab (40 courses), SAS (38 courses), and SPSS (36 courses). The BMDP package was reported in use in 17 courses. Minitab has more of an instructional orientation than the other three, and over 70 percent of its use was in undergraduate courses. The other three are intended for research-oriented data analysis, and about 60 percent of the courses using these packages were graduate courses. This survey only included statistics courses taught in departments of mathematics and/or statistics; many statistics courses are taught in other departments, and these probably make even greater use of data analysis software packages. The only other software package reported in use by more than one respondent was the Tanis package (reported in four upper-level undergraduate courses).

Computer-oriented, published materials are used most often with software packages. Specifically, of the 81 courses in which published material was used, 75 used manuals for one of the four software packages listed above. The Minitab handbook was used in 33 courses (83 percent of those in which the package was used). The data analysis packages (SAS, SPSS, BMDP) all had their manuals in use in about half of the courses using the software. The only computer-oriented textbook reported in use was Statistical Analysis: A Computer Oriented Approach by Afifi and Azen. This book presents statistics with the assumption that a data analysis package is available. It was reported in use in two graduate courses.

Because of the computational orientation of the computer use in statistics, there is still a heavy use of batch mode (42 percent of respondents) and large mainframe computers (73 percent). The trend away from batch toward time-sharing is present in statistics, but the move is slower than in many other disciplines.

Computer Use in Calculus

Of the traditional undergraduate mathematics courses, calculus was the first to have significant amounts of computing grafted on, and it still dominates in this regard. The type of use here is more heavily oriented toward problem-solving than for all mathematics courses, less toward simulation or tutorial and drill activities. A great deal of instruction in programming is associated with single-variable calculus, very little with multivariable calculus.

The pattern of materials in use has shifted somewhat since our last survey. The most popular computer-calculus text (but still not in widespread use) is Smith's Interface: Calculus and the Computer (see the bibliography). The only other texts mentioned by more than one respondent were Stroyan, Orth, Leinbach, and Dorn-Bitter-Hector. The last two were more popular in our previous survey, but Smith and Orth were relatively new then, and Stroyan was not yet in print. The leading text in the previous survey was the CRICISAM book, which has virtually disappeared, as did several of the others mentioned last time.

Computer Use in Linear Algebra

As was the case with calculus, activity in linear algebra is oriented more toward problem-solving, less toward simulation, tutorial, or drill. But much less programming instruction is associated with this course. The usual type of computing activity relieves the student of routine but tedious computations to allow more attention to the central ideas. The leading texts in this area are McLaughlin, Williams, and Fraleigh. (Note that two of the three are CONDUIT packages.)

Computer Use in Differential Equations

It is now almost standard for a differential equations course to include at least a brief unit on numerical methods, although the computation may be done (with some difficulty) on a calculator. At any rate, there is growing recognition that a course that includes only analytic methods of solution is a fraud, since these methods will seldom be ones needed in practice. This conviction is reflected in the fact that virtually every new book on differential equations being released includes a chapter on numerical methods. A few of the better ones are listed in this bibliography. The ones mentioned most often by our respondents were Hagin and Braun. In this course, both problem-solving (numerical solution of differential equations) and simulation (the same thing, in an applied context, and perhaps with graphical output) appear often; other activities appear very little. This course is a natural for graphics, and we expect that the present crude character-graphics programs will be replaced as graphics terminals and micros become more widespread.

Computer Use in Finite Mathematics, Liberal Arts Mathematics, and Teacher Education

These courses are grouped together because the boundary lines between them are fuzzy. Typical topics for inclusion in such courses are sets, symbolic logic, finite combinatorics, matrices, elementary linear programming, finite probability, Markov chains, and elementary statistics. If the course is titled Finite Mathematics, the emphasis may be more on problem-solving; if Liberal Arts, more on conceptual relationships and patterns of thought. If there are enough prospective (elementary and junior high) teachers to be taught, there may be more emphasis on arithmetic and numeration systems, and on statistics (IQ's, stanines, etc.), but otherwise these students are likely to satisfy a requirement by taking one of the other types of courses.

In all three cases, a new feature that is becoming standard is a unit on programming (usually in BASIC) and elementary concepts about computers. Some of this may be used for problem-solving and simulation (both more likely in finite math courses), and some of the freshman-level drill and tutorial activities take place in these courses. The most popular computer-related books in the finite math area are Dorn-McCracken, Anton-Kolman, and

Williams, and in the liberal arts category, Smith. No respondent mentioned any such book in connection with a course specifically aimed at teachers.

Computer Use in Precalculus Mathematics

The subject matter for these courses is algebra, trigonometry, elementary functions, and/or analytic geometry. They are often considered remedial (depending on college entrance requirements), sometimes terminal (basic skills), sometimes leading toward a standard calculus sequence (as the name suggests). In this area, the computer is much more likely to be used for drill, tutorial, instructional management, and test generation and scoring, and much less for problem-solving, simulation, or programming instruction. The only text mentioned more than once was LeCuyer. But note that the primary activities here require software support, not a student text. Most of the software systems developed for precalculus courses are heavily site-dependent. One that is not (and that shows some promise of adding something useful to drill and practice) is the package developed by Detmer and Smullen.

Computer Use in Operations Research, Modeling, and Linear Programming

These are areas that resemble computer science and numerical analysis in that computer use is often mandatory, sophisticated, well-understood, and carried out by packaged routines provided on large computing systems. These are also courses that are likely to be taught in departments other than mathematics in schools large enough to support, for example, a department of operations research. The only reason for not discussing these courses separately, as we did with the others, is because there are so few of them. Computers are used in these courses primarily for problem-solving, simulation, and data analysis. However, solving a problem in one of these areas is likely to mean much more than it does in calculus, and the simulations are likely to be much more ambitious than in a differential equations course.

Computer Use in Computer Science and Numerical Analysis

While we have disavowed any intention to discuss these areas, our survey showed a few things about textbooks that may be of interest. The most popular computer science book (at least for courses taught in mathematics departments) is that by Gear (SRA). There were many books in use for numerical analysis, but the most popular ones were Stark, Gerald, Conte-deBoor, and Johnson-Riess. A new book that is already attracting attention is Burden-Faires-Reynolds. There were literally dozens of programming texts identified in the survey--far too many to single out only a few.

Computer Use in Other Mathematics Courses

For the other courses listed in table 4, the responses were few in number and scattered, but definitely growing from our previous survey. The message for mathematicians is that there is a potential use for computers in practically every course in the curriculum. Good materials already exist for number theory, symbolic logic, and probability. Little seems to have been done yet with organized materials for modern or abstract algebra courses. One would expect that graphics devices would be put to work in geometry and topology courses, and they already have been for the study of Fourier analysis, for example, in advanced calculus.

5. Prospects for the Future

Since the bulk of the materials development in mathematics has been for courses in the calculus/linear algebra/differential equations range, the unmet needs are now largely at the lowest and highest levels of the course spectrum. On the one hand, much remains to be done in the development of cost-effective CAI, CMI, and CATC for large enrollment, remedial precalculus courses. On the other hand, there is very little available in the way of organized materials for exploration of algebraic structures in an abstract algebra course, for example, or for the use of graphics in an advanced calculus or beginning topology course.

An upper-level course for which a new development is under way is linear programming. The existing materials range from self-contained problem solvers (a good example is the LINPRO program in the HP User Contributed Library) to sophisticated production-type packages, such as IBM's MPS. A new teaching-oriented package will utilize a program that does one simplex step at a time and allows the student to make decisions interactively about such things as the location of the next pivot.

In those areas where good supplementary materials now exist, the next phase will be greater integration of computer materials into standard textbooks, thus making the supplements obsolete. (This has already begun, but the process is slow, and supplements will be with us for some time yet.)

The greatest need in statistics also is the development of textbooks that integrate the use of the computer into the course. Many of the survey respondents who are using the computer in their statistics courses are also using texts that are written as if computers did not exist. Several textbooks have attempted this integration, but none of these has received widespread acceptance. There have been many reasons for this, but one that is unique to the computer orientation of the texts is that many of the teachers of statistics were not familiar enough with computers and did not have time to learn more.

Exploratory data analysis, made popular by J.W. Tukey, is having a great impact on statistics courses oriented toward data analysis. There will be an increased use of the computer to implement the techniques, as well as to improve student understanding of the concepts involved. Packages have already been developed that incorporate these techniques, and an enhanced version of Minitab will include them.

With computer costs decreasing rapidly, and with the coming of the microcomputer, many problems can be overcome. The microcomputer also will influence the availability of and practicality of computer graphics. Some materials are currently under development that utilize graphics, but transferability and the cost of the equipment have been deterrents in the past. Microcomputers with graphics capabilities will facilitate these applications in both mathematics and statistics.

The effective use of CAI beyond the routine drill and practice level, especially in highly conceptual courses like mathematics, appears to depend on better communications devices than low-speed teletypes with limited character sets, restricted direction of motion, and uncertain response times from a time-shared computer. In addition to graphics displays, microcomputers can already provide graphics tablet, touch-sense, or light pen input, controllable response time, tone generators, and voice synthesizers, and in the not-too-distant future, they will have videodisc capabilities as well. While it won't happen quickly, there will eventually be true CAI at all levels of mathematics. An example that already exists is the VOCAL authoring system, developed by Patrick Suppes at Stanford, which uses a voice synthesizer to give auditory information (in addition to visual information on a CRT display) to the student, under program contol. An application of this system to a course in symbolic logic is described in a paper by Tryg Ager and James MacDonald in the NECC Proceedings.

We predicted in our previous reports that systems like PLATO and MACSYMA would have little impact on college mathematics for the foreseeable future. With respect to PLATO, that is more certain now, since there is little appropriate courseware on the system now, and the capabilities of the system are rapidly being exceeded by micros, at a fraction of the cost and under total control of the user. MACSYMA could have some value, especially in upper-level and applied courses, if the attempt to provide it over EDUNET had not failed. It is safe to say that it won't appear on a micro any time soon (but muMATH, a much smaller symbolic manipulation system, is available on several micros). According to rumors, MACSYMA may soon become a commercial product, like SPSS and SAS, and it may then be available on a more widespread bassis, including possibly on EDUNET.

At the other end of the technological scale, calculator capabilities continue to develop, and the distinction between them and computers is beginning to blur. Ohio State University has a large-scale project under way to develop materials to support the use of programmable calculators in calculus courses. Another of our predictions in the previous report was that teachers of mathematics would continue to move in the direction of finding an appropriate mix of the available computational tools to support their educational objectives, and we continue to see that process at work.

In the three years since our previous report was written, developments have been as we expected, except that we did not really appreciate how fast changes in micros would come on the scene. Our summary of future prospects then is still appropriate now, and we indulge in the luxury of quoting ourselves:

> "To summarize, the following developments point toward a rapid increase in the use of numerical computation in mathematics courses: pressures from outside the mathematics departments; availability of calculators and minicomputers; and the availability of transferable, easy-to-use packages for the novice, supported by sound text materials, and capable of running on existing equipment. It may be an overstatement to call this a revolutionary change, but it appears that mathematics courses (other than those attended by small numbers of majors headed for graduate study in pure mathematics) will look very different from those of 20 or even 10 years ago. The potentially dramatic effects of computer graphics on the teaching of mathematics will probably not appear on a widespread basis as fast as their developers predict, primarily for economic reasons. Developments in hardware and software will certainly continue, and costs will continue to decrease. However, the impact of these developments will probably continue to be limited to relatively few campuses until there is a consensus among mathematics teachers that we can no longer afford to do without these tools."

6. Information Sources

Journals

Note that abbreviations in parentheses are used in the next section to indicate sources of reviews.

The American Mathematical Monthly (AMM)

The most widely read and influential journal for college teachers of mathematics. Percentage of computer-related content is small but growing. Telegraphic reviews especially helpful for keeping track of new books and materials.

American Statistician

Statistical Computing department and Teacher's Corner are particularly helpful.

Computing Reviews (CR)

Reviewing journal of the Association for Computing Machinery. Includes reviews of mathematics and statistics textbooks that involve computing.

Creative Computing (CC)

Oriented toward microcomputers and their uses. Good reviews of equipment and software. Educational applications tend to be more at the secondary level than at the collegiate. Lots of games and business applications as well.

Educational Studies in Mathematics

Published in Holland. Contains many computer-related articles.

Journal of the American Statistical Association (JASA)

Publishes useful book reviews.

Mathematics Magazine (MM)

Intended to reach undergraduates directly, but many useful articles for instructors as well. Computer-related content increasing gradually. Helpful brief summaries of current books and articles.

Mathematics Teacher (MT)

Many articles by college faculty members, but readers are primarily high school and junior college teachers. Quite a few computer-related articles, plus announcements of products, services, and publications involving computers.

SIAM Review (SR)

Classroom Notes section for significant applications of mathematics suitable for classroom presentation, many of which involve the use of computers. Helpful book reviews.

Two-Year College Mathematics Journal (TYCMJ)

Contains a Computer Corner section for short notes, plus occasional longer articles with computer-related content.

Other Information Sources

Ad Hoc Committee on Applied Mathematics Training (AMTRAC). The Role of Applications in the Undergraduate Mathematics Curriculum. Washington: National Academy of Sciences, 1979.

Report of a National Research Council committee chaired by Peter Hilton. Argues for applications in the mathematics curriculum, basic competence in computer programming for every mathematics major, and use of students' computing knowledge in appropriate courses.

Committee on the Undergraduate Program in Mathematics. Recommendations for an Undergraduate Program in Computational Mathematics. Berkeley, CA: CUPM, 1971.

Committee on the Undergraduate Program in Mathematics. Recommendations on Undergraduate Mathematics Courses Involving Computing. Berkeley, CA: CUPM, 1972.

Committee on the Undergraduate Program in Mathematics. A Compendium of CUPM Recommendations. Berkeley, CA: CUPM, 1975.

Includes the two previous items and the 1965 GCMC report. Telegraphic review: AMM 83 (1976):73.

Conference on Computers in the Undergraduate Curricula (CCUC). Iowa City: The University of Iowa Weeg Computing Center, 1970-1978.

Annual proceedings, CCUC/1 through CCUC/9. The mathematics and statistics sections in numbers 1, 2, 3, 5, 8, and 9 are particularly useful. Replaced by the National Educational Computing Conference in 1979 (see below).

Garland, S.J., ed. Calculus and Computing. Washington: American Mathematical Society and Mathematical Association of America, 1975.

Pamphlet presenting case studies from nine different schools, sample problems, help on getting started, and a bibliography.

LaSalle, J.P., ed. The Influence of Computing on Mathematical Research and Education. Providence, RI: American Mathematical Society, 1974.

Proceedings of the AMS Symposium in Applied Mathematics held at the University of Montana, August, 1973. CR 16 (1975):Review No. 28683.

Milton, R.C., and Nelder, J.A., eds. Statistical Computation. New York: Academic Press, 1969.

Proceedings of a conference. Includes two papers on teaching of statistics with computers, plus several other pertinent papers. AMM 77 (1970):908.

Undergraduate Mathematics Applications Project (UMAP). Index and Descriptions of Available Mathematics Modules. Newton, MA: EDC/UMAP.

Lists hundreds of applications modules in various stages of development; relatively few are specifically computer-related. Units in final stage are thoroughly class-tested and reviewed. Other UMAP publications (regularly updated) include: UMAP Catalog, Unit Samplers, UMAP Projections (newsletter), and various monographs.

National Educational Computing Conference (NECC). Iowa City: The University of Iowa Weeg Computing Center, 1979.

NECC is the successor to CCUC. Merger with several other groups and conferences resulted in fewer discipline-oriented papers, more emphasis on new technology, and higher overall quality. Only two papers on mathematics, both containing useful information on computer graphics.

7. Materials of Interest

The following materials have been identified as having potential use for mathematics instruction. Additional information about these units can be obtained by writing to the authors or publishers. For information about those materials distributed by CONDUIT, see the CONDUIT Catalog. Journal abbreviations refer to the list in the previous section. Most reviews in the Monthly (AMM) are telegraphic reviews consisting of complete bibliographic information and brief comments.

Calculus

Allen, R.C., Jr., and Wing, M.C. Problems for a Computer Oriented Calculus Course. Englewood Cliffs: Prentice-Hall, 1973.

Consists of statements of problems for a calculus lab, selected solutions (with programs and output), an appendix on FORTRAN, and accompanying solutions manual. AMM 81 (1974): 805.

Barr, R.C.; Gallie, T.M., Jr.; Hodel, M.J.; Hodel, R.E.; Murray, F.J.; Smith, D.A.; and Smith, D.A., II. MATHPROGRAM: A Computer Supplement for Calculus. Iowa City: CONDUIT, 1980.

Package consists of a single program to tabulate up to seven sequences (possibly interrelated and defined recursively), a student manual with an extensive problem set, and an instructor's manual. Students use the program to solve problems in single-variable and multivariable calculus by inserting definitions of algorithms in it before running the program. Available in BASIC from CONDUIT, and in FORTRAN, PL/I, and APL versions from the authors at Duke University.

Bogart, K., and Vitale, M. The Calculus of Population. Wentworth, NH: COMPress, 1974.

Short text on calculus of elementary functions, motivated by problems in population growth and supported by computer applications.

Dorn, W.S.; Hector, D.L.; and Bitter, G.G. Computer Applications for Calculus. Boston: Prindle, Weber, and Schmidt, 1972.

Contains many possible applications of computing in calculus. May be more useful as a source of ideas for instructors than as a text for students. The programs are in FORTRAN and BASIC, with appendices on each language. For a review, see AMM 80 (1973):103.

Fossum, T.V., and Gatterdam, R.W. Calculus and the Computer: An Approach to Problem Solving. Glenview, IL: Scott, Foresman and Co., 1980.

Supplementary text intended to illustrate and reinforce concepts and develop algorithmic problem-solving techniques, with emphasis on analysis and interpretation of numerical results. Sixteen "core" sections, five "supplementary" sections, and appendices on flowcharts, BASIC, and error analysis. Each section contains at least one algorithm presented both by flowchart and by BASIC program.

Hamming, R.W. Calculus and the Computer Revolution. Boston: Houghton Mifflin, 1968.

Should be required reading for instructors, but may be too terse for students. No computer problems or programming are included. AMM 76 (1969):576. MT 63 (1970):282.

Henriksen, M., and Lees, M. Single Variable Calculus with an Introduction to Numerical Methods. New York: Worth Publishers, 1970.

Integrated calculus text with numerical applications, appropriate for honors students. AMM 78 (1971):556-557.

Horn, R. Notes for a Calculus Computer Laboratory. Baltimore: Department of Mathematical Sciences, Johns Hopkins University, 1976.

Packaged programs in BASIC, plus an excellent problem set. To appear as a CONDUIT package.

Lax, P.D.; Burstein, S.Z.; and Lax, A. Calculus with Applications and Computing, Vols. 1 and 2. New York: Springer-Verlag, 1976, 1979.

Represents a restructuring of the calculus course as an introduction to applied mathematics. The appendix contains FORTRAN solutions to several problems. AMM 83 (1976):757.

Leinbach, L.C. Calculus with the Computer: A Laboratory Manual. Englewood Cliffs: Prentice-Hall, 1974.

Student-oriented manual intended to supplement any calculus course, with appendices on BASIC and FORTRAN and a solutions manual. AMM 81 (1974):190.

Lynch, R.V.; Ostberg, D.R.; and Kuller, R.G. Calculus with Computer Applications. Lexington, MA: Xerox, 1973.

Ambitious calculus text with an appendix on computer applications and numerical methods. AMM 80 (1973):1082.

McCarty, G. Calculator Calculus. Palo Alto: Page-Ficklin, 1975.

An alternative to many of the books in this list, covering most of the same topics, but with computational exercises to be done with a calculator. Could be used to introduce numerical methods early, with use of the computer deferred until it becomes clearly necessary for problems beyond the reach of the calculator. AMM 83 (1976):394. SR 20 (1978): 196-197.

McNeary, S.S. Introduction to Computational Methods for Students of Calculus. Englewood Cliffs: Prentice-Hall, 1973.

Text for a course parallel to or following second-semester calculus. The programs use FORTRAN. AMM 80 (1973):962. CR 15 (1974):Review No. 26316.

Orth, D.L. Calculus in a New Key. Swarthmore, PA: APL Press, 1976.

A reworking of traditional calculus topics in an algebraic and algorithmic framework, using APL notation and concepts throughout. CR 19 (1978):Review No. 32480. CC 3,5 (1977): 102.

Shapiro, L. Individualized Supplementary Calculus Instruction (ISCI). Minneapolis: Consulting Group on Instructional Design, University of Minnesota.

A computer-tutor program for diagnosing student difficulties with problems whose solutions have been attempted off-line. Program has been moved successfully to several different computers and can also be accessed via EDUNET. Related article appears in AMM 84 (1977):476-481.

Smith, D.A. Interface: Calculus and the Computer. Boston: Houghton Mifflin, 1976.

Student-oriented enrichment text and lab manual, with appendices on FORTRAN, BASIC, and PL/I, and an instructor's manual with complete solutions and suggestions for use. Also available with two character-graphics programs as CONDUIT package #MTH105. AMM 83 (1976):756. CC 3,1 (Jan. 1977).

Smith, D.A. Surface: A Three-Dimensional Graphics Module for Multivariable Calculus. Iowa City: CONDUIT, 1978.

Character graphics package to support the study of functions of two variables. Program available in FORTRAN or BASIC, plus student manual. Related article appears in MM 50 (1977):143-147.

Stenberg, W., and Walker, R.J. Calculus: A Computer Oriented Presentation. Tallahassee: Center for Research in College Instruction of Science and Mathematics (CRICISAM), Florida State University, 1968.

Integrated course presenting a nontraditional ordering of topics. Widely used for a number of years, but a recent ad in AMM announced liquidation of remaining stock by CRICISAM. Related publications include: AMM 78 (1971): 284-291. TYCMJ (Fall 1971):51-54.

Stroyan, K.D. Computer Laboratory in Calculus and Linear Algebra. Iowa City: CONDUIT, 1978.

Package consists of a laboratory manual and 27 BASIC programs to support a four-semester calculus sequence with linear algebra in the third semester. AMM 86 (1979):320.

Statistics and Probability

Afifi, A., and Azen, S. Statistical Analysis: A Computer Oriented Presentation, second edition. New York: Academic Press, 1979.

A textbook which integrates the use of data analysis packages into an advanced undergraduate or graduate course with emphasis on applied statistical techniques. JASA 69 (1974):279. AMM 86 (1979):517.

Dershem, H. Computer Exercises for Elementary Statistics. Wentworth, NH: COMPress, 1979.

A package containing 49 exercises, 28 FORTRAN subprograms, and 5 data sets for use in a precalculus statistics course. To appear as a CONDUIT package.

Dixon, W.J., ed. BMDP Biomedial Computer Programs. Berkeley: University of California Press, 1975.

Gilbert, N. Statistics. Philadelphia: Saunders, 1976.

Descriptive, inferential, and nonparametric statistics for nonmathematics majors. Computational exercises using computer programs provided on punched cards with accompanying manual. AMM 84 (1977):229.

Groeneveld, R.A. An Introduction to Probability and Statistics Using BASIC. New York: Marcel Dekker, 1979.

Intended for a course following calculus of one variable. Forty-eight short, interactive BASIC programs are provided for examples and simulations. Brief introduction to BASIC in an appendix. All programs in the text are available on tape from the author at Iowa State University. AMM 86 (1979):517.

Klecka, W.R.; Nie, N.H.; and Hull, C.H. SPSS Primer. New York: McGraw-Hill, 1975.

Good handbook for courses using SPSS. See also Nie, et al. below.

Kossack, C.F., and Henschke, C.I. Introduction to Statistics and Computer Programming. San Francisco: Holden-Day, 1975.

Introductory statistics text for students of social sciences; includes three chapters on FORTRAN and numerous FORTRAN programs which illustrate statistical concepts. CR 17 (1976):Review No. 29618. AMM 84 (1977):670.

McNeil, D.R. Interactive Data Analysis: A Practical Primer. New York: Wiley, 1977.

A supplement for a course in exploratory data analysis including APL and FORTRAN implementations of the techniques. JASA 73 (1978):887. CC 3,6 (Nov. 1977):128.

Nie, N.H.; Hull, C.H.; Jenkins, J.G.; Steinbrenner, K.; and Bent, D.H. *SPSS: Statistical Package for the Social Sciences*, *second edition*. New York: McGraw-Hill, 1975.

Reference manual for SPSS as well as for the statistical techniques available with the package. AMM 83 (1976):77. For those using version 7 or 8 of SPSS, there is an SPSS Update, also published by McGraw-Hill, 1979.

Richardson, R.H., and Stones, D.H. *Quantitative Experimental Analysis*. Iowa City: CONDUIT, 1978.

Seven modules designed for use with an applied statistics course. Accompanying FORTRAN programs are interactive and utilize random sampling and graphical analysis. No calculus prerequisite.

Ryan, T.A.; Joiner, B.L.; and Ryan, B.F. *MINITAB II Reference Manual*. University Park, PA: Statistics Department, Pennsylvania State University.

Intended for precalculus statistics courses; system contains computational, plotting, and simulation routines with extensive error-checking and diagnostics; available in transferable form.

Ryan, T.A.; Joiner, B.L.; and Ryan, D.F. *MINITAB Student Handbook*. North Scituate, MA: Duxbury Press. Now available from Wadsworth Publishing Co., Belmont, CA.

Supplemental text for statistics course which uses the Minitab package. JASA 72 (1977):933.

SAS Introductory Guide. Raleigh, NC: SAS Institute, 1978.

Beginner's guide to the Statistical Analysis System (SAS). See also the next listing.

SAS User's Guide, *1979 edition*. Raleigh, NC: SAS Institute, 1979.

The complete story on SAS in a very readable form.

Scalzo, F., and Hughes, R. *Elementary Computer-Assisted Statistics*, *revised edition*. New York: Van Nostrand, 1978.

Elementary statistics text with accompanying BASIC programs

for performing calculations. AMM 84 (1977):670. CR 18 (1977). Review: 86 (1979):607.

Snell, J.L. Introduction to Probability Theory with Computing. Englewood Cliffs: Prentice-Hall, 1975.

Introductory probability text; makes use of BASIC programs to illustrate concepts by simulation. AMM 82 (1975):1031.

Tanis, E. Laboratory Manual for Probability and Statistical Inference. Iowa City: CONDUIT, 1978.

Laboratory exercises for mathematical statistics course, with 58 batch or interactive FORTRAN subprograms.

Weed, H.D. Descriptive Statistics, second edition. Wentworth, NH: COMPress, 1978.

Supplement to introductory statistics texts; includes four BASIC programs for elementary descriptive statistics calculations. Also available as CONDUIT package #STA114.

Linear Algebra

Agnew, J., and Knapp, R.C. Linear Algebra with Applications. Monterey, CA: Brooks/Cole, 1978.

Well-written, one-semester text with applications and computer programs in every chapter. AMM 86 (1979):70.

Fraleigh, J.B. Computer Supplement for Linear Algebra. Iowa City: CONDUIT, 1977.

Package consisting of seven BASIC programs and a supplementary text with computer projects to enhance standard linear algebra courses.

Kolman, B. Introductory Linear Algebra with Applications. New York: Macmillan, 1976.

Includes a chapter on numerical linear algebra. Appendix contains many computer projects of varying levels of difficulty, plus comments on APL and BASIC. AMM 83 (1076):393.

McLaughlin, D.E. A Computer Oriented Course in Linear Algebra. Iowa City: CONDUIT, 1974.

Package consisting of a textbook and FORTRAN subroutines for reduction to echelon form, Gram-Schmidt process, characteristic polynomial, and simplex algorithm. Uses computing to illustrate theory and to emphasize the algorithmic nature of linear algebra. Exercises ask students to write simple programs using the supplied subroutines.

Steinberg, D.I. Computational Matrix Algebra. New York: McGraw-Hill, 1974.

Standard sophomore-level text with coverage through eigenvalues and Jordan form; emphasis on computational methods. No programs are provided or required. CR 16 (1975):Review No. 27663. AMM 81 (1974):926.

Williams, G. Computational Linear Algebra with Models. Boston: Allyn and Bacon, 1975.

Covers standard topics plus numerical methods with an unusually broad array of applications. About 20 BASIC programs and accompanying computer exercises are provided in an appendix. AMM 82 (1975):543.

Differential Equations

Boyce, W.E., and DiPrima, R.C. Elementary Differential Equations and Boundary Value Problems, third edition. New York: Wiley, 1977.

Standard text for post-calculus courses up to one year in length; many different one-semester courses can be extracted. Thorough chapter on numerical methods: no programs provided. Also available in shorter version without material on boundary value problems. AMM 84 (1977):664-665, 752; 86 (1979):599-600.

Braun, M. Differential Equations and their Applications, second edition. New York: Springer-Verlag, 1978.

Modern, complete text in ODE's with many interesting applications. FORTRAN and APL programs illustrate numerical solutions. An appendix gives a brief introduction to APL. AMM 82 (1975):1029; 84 (1977):664-665. SR 21 (1979):264-266.

Buck, R.C., and Buck, E.F. Introduction to Differential Equations. Boston: Houghton Mifflin, 1976.

Standard text for a one-semester or two-quarter course; one chapter and an appendix on numerical methods. No programs provided; use of a pocket calculator is suggested for numerical problems. AMM 83 (1976):753-754.

Calter, P. Solution of Differential Equations by Graphical and Numerical Means. Newton, MA: EDC/UMAP, 1976.

Supplementary module for calculus or differential equations courses to present physical and biological applications and means of solving them. Can be covered in about a week.

Hagin, F.G. A First Course in Differential Equations. Englewood Cliffs: Prentice-Hall, 1975.

Standard one-semester text in which numerical methods are taken up early and often (a little in each of the first two chapters, all of chapter 3, and computational considerations in the chapter on series). Includes flowcharts and some sample programs in BASIC and FORTRAN. AMM 83 (1976):753-754.

McLaughln, D.E. Numerical Solution of Ordinary Differential Equations. Iowa City: Regional Computer Center, University of Iowa, 1973.

Multilithed course notes, intended as a computer-oriented supplement to a standard differential equations course.

Van Iwaarden, J.L. Elementary Numerical Techniques for Ordinary Differential Equations. Wentworth, NH: COMPress, 1977.

Package consisting of student manual, instructor's manual and 19 BASIC programs to supplement standard ODE courses; units may be taken up one at a time when the corresponding analytic material is being covered. To appear as a CONDUIT package.

Ziebur, A.D. Topics in Differential Equations. Belmont, CA: Dickenson, 1970.

Covers the standard topics in ordinary differential equations; the computer is used as a tool to teach theory. AMM 79 (1972):1148-1149. Zentralbatt fur Mathematik 288 (1972):158, Review no. 34002.

Finite Mathematics

Anton, H., and Kolman, B. Applied Finite Mathematics, second edition. New York: Academic Press, 1978.

Well-written book with good problems, examples, applications. Chapter on computing uses BASIC (replacing FORTRAN in the first edition). Also available in expanded edition with intuitive introduction to calculus. AMM 85 (1978):511; 86 (1979):140.

Dorn, W.S., and McCracken, D.D. Introductory Finite Mathematics with Computing. New York: Wiley, 1976.

Computer use is fully integrated using BASIC. CR 17 (1976): Review No. 29959. AMM 83 (1976):394.

Scalzo, F., and Hughes, R. A Computer Approach to Introductory College Mathematics. New York: Petrocelli/Charter, 1977.

Topics include algebra, matrices, elementary linear programming, symbolic logic, elementary probability and statistics, and programs provided in the text to solve problems related to every topic. AMM 85 (1978):63.

Williams, G. Finite Mathematics with Models. Boston: Allyn and Bacon, 1976.

Contains an early chapter on computing and an appendix on BASIC. Many BASIC programs and computer exercises appear throughout the text, ranging from multiplying a matrix by a scalar to simple games of strategy. AMM 83 (1976):394.

Liberal Arts Mathematics

Dorn, W.S., and Greenberg, H.J. Mathematics and Computing: With FORTRAN Programming. New York: Wiley, 1967.

Intended for a precalculus, liberal arts, or teacher education course. Covers topics in calculus, finite mathematics, linear algebra, logic and probability. AMM 75 (1968):103.

Smith, K.J. The Nature of Modern Mathematics, second edition. Monterey, CA: Brooks/Cole, 1976.

Very attractive text covering the nature of mathematical thought, numeration systems, computers, elementary abstract algebra, number theory, logic, geometry, combinatorics, probability, and statistics. Early chapter on computers contains exercises using a computer. AMM 81 (1974):1129-1130; 83 (1976):579.

Precalculus Mathematics

Burrowes, T.C., and Burrowes, S.K. Elementary Functions: An Algorithmic Approach. New York: Intext, 1974.

Emphasizes algorithms and flowcharts; computer use is optional. Appendices on BASIC and FORTRAN. Programs are provided in FORTRAN for graphing, roots by interval-halving, function evaluation, and rational roots of integer polynomials. Opportunities throughout for students to write programs for other problem solving.

Detmer, R.C., and Smullen, C.W., III. Algebra Drill and Practice. Iowa City: CONDUIT, 1979.

Well-documented CAI package; consists of nine modules covering various algebraic skills. Three of the modules deal with word problems (rectangles, distances, and mixtures in solution) and offer the student four levels of difficulty.

Higgins, G.A., Jr. The Elementary Functions: An Algorithmic Approach. Englewood Cliffs: Prentice-Hall, 1974.

Computer use integrated throughout in the form of BASIC programs and computer exercises. Knowledge of BASIC is assumed. AMM 81 (1974):104. CC 2,5 (Sept. 1976):96.

Iverson, K.E. Algebra: An Algorithmic Approach. Reading, MA: Addison-Wesley, 1971. Now available from APL Press, Swarthmore, PA.

Covers elementary functions using APL notation throughout. AMM 81 (1974):420. CR 13 (1972):Review No. 22530. CC 3,5 (Sept. 1977):102.

Iverson, K.E. Elementary Analysis. Swarthmore, PA: APL Press, 1976.

Covers precalculus algebra, elementary transcendental functions, derivatives and antiderivatives, complex numbers, conic sections, and recursive functions, all with APL notation. CR 18 (1977):Review No. 31726. CC 3,5 (Sept. 1977):102.

LeCuyer, E.J. Introduction to College Mathematics with a Programming Language. New York: Springer-Verlag, 1978.

Innovative text for a full-year course covering sets, logic, elementary linear algebra, graphing of functions, transcendental functions, brief introductions to differential and integral calculus, probability, and statistics. Appendix on APL; conventional and APL notation used in parallel throughout the text. CR 19 (1978):Review No. 33650. AMM 85 (1978):693.

Wallace, W. Functions and Their Graphs Using a Computing Terminal. Oshkosh, WI: University of Wisconsin, 1978.

Multilithed notes and BASIC programs for the study of graphs of functions via character-graphics plots. Package is still in a state of development.

Number Theory

Kirch, A.M. Elementary Number Theory: A Computer Approach. New York: Intext, 1974.

Solid text which applies the computer in expected ways. The programs are in FORTRAN. AMM 81 (1974):926; 84 (1977):398.

Malm, D.E. A Computer Laboratory Manual for Number Theory. Wentworth, NH: COMPress, 1978.

Supplement to standard text to treat subject as an experimental science. For each topic, includes descriptions of concepts; experiments for before, during, and after study of topic; references. Instructor's manual, approximately 40 programs in BASIC. AMM 86 (1979):320. (To appear as a CONDUIT package.)

Symbolic Logic

Moor, J., and Nelson, J. BERTIE. Wentworth, NH: COMPress, 1974.

Package consisting of an interactive BASIC program and a student/instructor manual. Intended to teach the skills needed for natural deductive derivations and to enhance students' ability to write and recognize well-formed formulas. Uses the Gustason-Ulrich system of natural deduction. Also available as CONDUIT package #MTH047.