Computers in Undergraduate Teaching:

1977 CONDUIT State of the Art Reports in Selected Disciplines

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SECTION IV

COMPUTERS IN TEACHING MATHEMATICS

A STATE OF THE ART REPORT

Prepared by the CONDUIT Mathematics Committee

May, 1977

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I. BACKGROUND AND CURRENT PATTERNS

□□CURRICULUM DEVELOPMENT

Although many of the prominent developers and users of computers were originally trained as mathematicians, computers seem to have had less impact on undergraduate education in mathematics than they have had in the physical sciences or in business. To the average man in the street, mathematics and computers are synonomous, but even the educated nonmathematician is surprised at how seldom computers are used in teaching mathematics.

As nearly everyone knows, the decade of the sixties was a time of revolution in the mathematics curriculum of the primary and secondary schools. Concurrent with these changes was a quieter reorganization of the curriculum in the 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 program in 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 impact 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 in the classroom. Nevertheless, at this time, scores of individuals were experimenting with the use of 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, some summer institutes in computing and mathematics for college teachers, and a number of large curriculum development projects of which mathematics was a part.

Although the number of apparently successful small-scale trials of computer-based instructional materials is by now fairly large, it is still too early to claim that there is a revolution in the classroom. With respect to curriculum change, the mathematical community continues to take a fairly conservative stance. However, some inroads are being made. One very positive sign is that the influential CUPM mentioned above 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 impact 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.

A further sign that changes are afoot in the mathematics classroom is provided by the growing body of computer-oriented materials now available to supplement a traditional course, or to replace it completely. Most of the activity is in the calculus and statistics areas, although some materials are available in precalculus mathematics, differential equations, linear algebra, number theory, symbolic logic, and finite mathematics. In both calculus and statistics, materials for an associated computer-oriented laboratory are appearing in increasing numbers. The commercial publishers, heretofore wary about getting into the business of marketing computer-oriented materials, are beginning to publish more materials of this nature. These are mostly hardcover texts for calculus and statistics courses, and soft-cover manuals for the associated laboratories. Apparently there is a great deal of material developed by individuals for their own courses that never moves from the originating site. (See Section II.)

An additional factor bearing on the trend in curriculum change is the changed 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. All of this activity tends to create a climate favorable to the introduction of computer-oriented instruction into the curriculum on a broad scale.

▫▫DEVELOPMENT OF MATERIALS

There is a need for a greater variety in all types of computer-oriented curriculum materials, but there is a special need for more material to use in the well-established post-calculus courses such as differential equations and linear algebra. With applied mathematics getting increasing attention, there is also now a need for completely new and innovative courses having computer support, such as courses in methods of optimization, mathematical-computer modeling, or graph theory and combinatorics (see Recommendations on Undergraduate Mathematics Courses Involving Computing, CUPM, 1972). More attention needs to be paid to graphics in all forms--from primitive plotting on a line printer or teletype, to computer generated films. And finally, there is a problem with incentives for the development of materials. In the present reward structure, the developer of curriculum materials frequently receives no monetary compensation, nor the prestige of a publication or points toward tenure. The equivalent time spent on traditional research has better payoff. It is true nowadays that computer-based curriculum material which takes the form of a stand-alone text may be published by a commercial house, which rewards the effort of development. However, if the material is largely software, it is difficult for the developer to get adequate recognition for his or her work.

▫▫ADVERTISING, PROMOTION, AND COMMUNICATION

In disseminating information concerning computer-oriented pedagogy to uninterested mathematicians, the multidisciplinary conferences of the CCUC type have little effect. Relatively few mathematicians attend such conferences or read the proceedings. A conference devoted only to mathematics, such as the 1973 Missoula conference sponsored by the American Mathematical Society and the Mathematical Association of America, reaches many more mathematics teachers and has the additional advantage of the presence of many highly regarded mathematicians. An important byproduct of the Missoula conference is the pamphlet Calculus and Computing, edited by Stephen Garland (AMS-MAA, 1975), which is a "state of the art" report in itself, but limited to one subject in mathematics. (See Section V for reference.)

More recently, the 1976 annual meeting of the American Mathematical Society included special sessions of invited papers on uses of the computer in teaching mathematics courses, on computers in the study of nonassociative rings and algebras, and on computations and algorithms in number theory. In addition, both this meeting and its predecessor a year earlier, included panel presentations by an NSF-funded workshop group based at Illinois Institute of Technology which is developing computer-based modular instructional materials in mathematics, physics, and chemistry. (For more information, contact Professor H. Weinstock, Physics Department, ITT, Chicago, Ill. 60616.) Several regional meetings of the Mathematical Association of America during the last few years have had special sessions on the instructional use of computers.

The most widely read and influential journal for college teachers of mathematics is the American Mathematical Monthly, published by the Mathematical Association of America. Since the start of the editorship of Alex Rosenberg in January, 1974, the Monthly has welcomed significant contributions related to the use of computers. (Rosenberg was chairman of CUPM and cochairperson of the panel that produced the 1972 CUPM recommendations referred to above.) The number of such contributions is still not large (two articles in 1973, five articles and three book reviews in 1974, eight articles in 1975), but there is great potential for reaching mathematics teachers through the Monthly, given the receptiveness of the entire editorial staff to computer-related material. The "Telegraphic Reviews" in the Monthly are very helpful for keeping abreast of new books.

Other important journals for reaching mathematics teachers are the Two-Year College Mathematics Journal (also published by MAA), and the Mathematics Teacher (NCTM, read primarily by high school and junior college teachers). Like the Monthly, these journals are receptive to computer-related articles, but depend primarily on contributed articles and reviews rather than on soliciting material on particular subjects. The Mathematics Teacher has averaged about six computer-related articles per year over the last three years; plus, it also notes about an average of 20 or more products, services, or publications involving computers. A majority of these articles are written by college faculty members, but the content is generally aimed at secondary teachers. The TYCMJ has had a "Computer Corner" section since September, 1974.

The MAA also publishes Mathematics Magazine, which is intended to reach undergraduates directly. Although hardly any computer-related articles have been published in this magazine in recent years, here too, there is great potential, because the new editors, Lynn Steen and Arthur Seebach, are very interested in publishing suitable computer-related material.

SIAM Review, published by the Society for Industrial and Applied Mathematics, has recently instituted a "Classroom Notes" section for significant applications of mathematics which are suitable for classroom use. While not specifically computer-oriented, it is likely that some of these notes will describe applications requiring use of a computer. The American Mathematical Society is oriented primarily toward research rather than education, but the programs and abstracts for the meetings mentioned above appear in the Notices of the AMS, and there will probably be more such sessions at AMS meetings in the future.

In the fall of 1974, a new journal, Creative Computing, appeared. This journal is devoted entirely to educational and recreational computing. Its impact cannot be assessed at this time, but its content to date has been more heavily oriented toward secondary rather than collegiate education.

One European journal, Educational Studies in Mathematics (published by D. Reidel Co. in Holland), has carried a large proportion of computer-related articles from its very first issue in 1968. Unfortunately, it seems not to be widely read in this country.

For courses in statistics, the Statistical Computing Department and the Teacher's Corner in The American Statistician are particularly helpful. In addition, the Journal of the American Statistical Association publishes useful book reviews.

DELIVERY OF MATERIALS

There seem to be no problems in delivery of computer-based instructional materials that are peculiar to mathematics. The commercial publishing houses, because of their already well-developed advertising and distribution systems, will continue to be effective in transporting the kind of mathematical material that fits well between two hard covers. To facilitate the exchange of individual programs, software packages, small course modules, and general information on computer-based curricular innovations, a national organization such as CONDUIT is potentially of great value to the mathematical community. Indeed, except for the type of information appropriate for journal publication, there does not seem to be any other mechanism available for this exchange.

II. SUMMARY OF SURVEY RESULTS

In November 1974, the CONDUIT Mathematics Advisory Committee conducted a survey to gather information on: (1) the ways in which the computer is presently being used in undergraduate mathematics and statistics instruction; and (2) sources of innovative computer-based materials for the teaching of mathematics and statistics.

A brief one-page questionnaire with cover letter was sent to the 2,700 departments of mathematics and departments of statistics of the two-year and four-year colleges and universities in the United States and Canada (as listed in the Mathematical Sciences Directory, prepared by the American Mathematical Society). The number of forms returned was 604. However, that figure is not meaningful by itself, due to varied patterns of response. From some schools, we received a response from a single individual concerning several different courses, either on a single form, or on multiple copies of the form. From other schools, we received a response from every individual who had participated in a computer-related course, and in some cases, from several instructors in the same course. About 8% of the forms received came from departments other than mathematics or statistics. (Most of these were departments that use statistics with computer assistance, and some were computer science departments.) The response rate from the target departments was about 18% (469 schools, some with separate departments of mathematics and statistics). Of these, about 10% indicated no use of the computer in teaching mathematics. It would be unrealistic to conclude, however, that 90% of the target departments make use of the computer, since the "no use" rate is surely much higher among the nonrespondents. A better guess might be that at least 20-25% of mathematics and/or statistics departments make some use of computers for educational purposes.

The problem of estimating level of usage is further complicated by the presence in the curriculum of courses which have used computers for as long as they have been available, such as numerical analysis, programming, and computer science. These courses are not offered everywhere, and where they are offered, they are likely to be taught in a computer science department, if there is one. However, many mathematics departments offer such courses, and numerical analysis, at least, is certainly mathematics. Since computer use for these types of courses is relatively well understood, standardized, and integral to the subject matter, the Committee has consistently felt that there is no essential role for CONDUIT in these areas. About one-third of the responding departments of mathematics indicated no use of the computer other than for numerical analysis, programming, and/or computer science courses.

Approximately one-fourth of the responding institutions were two-year (junior or community) colleges, and the remaining three-fourths were evenly divided between colleges and universities. The sizes of these institutions (by enrollment) were distributed about as one would expect, ranging from very small to very large, with about 70% in the 1,000 to 15,000 range, somewhat more below 5,000 than above. Forms were returned from 47 states, the District of Columbia, and Canada. Thus the sample appears to be representative of higher education in this country. (Only eight Canadian schools were represented.)

The questionnaire asked about mode of computer use and languages used. The dominant modes were described on the form as "timesharing" and "batch," which are slightly misleading terms. However, the respondents generally understood them, and in some cases corrected the form. By the term "timesharing," we meant conversational or interactive use of the computer, which usually involves timesharing, but might mean use of a minicomputer by a single person, or even use of a programmable calculator, in an extreme case. (One respondent from a small college in New England was an enthusiastic proponent of programmable calculators for teaching purposes in "all math courses.") On the other hand, by "batch," we meant punched card input/line printer output, whether or not programs were batched, and even if the computer happened to share time among many users. Since the misnomers are in common usage, the results probably indicate what we wanted to know: 46% timesharing, 24% batch, and 30% both.

On the matter of languages, a few respondents seemed inclined to list all the languages available on their system (or that they know), but most understood that we wanted to know about languages used in the courses being reported on. Not surprisingly, the dominant languages were FORTRAN (57%) and BASIC (52%), with APL reported by 15% and 35% mentioning other languages (PL/I, Algol, various local languages, and CAI). On both the matters of mode and language, it should be noted that the figures are percentages of respondents, roughly corresponding to institutions, but are not weighted by numbers of students enrolled or served. Thus one might guess that use of batch-process FORTRAN, for example, is understated on the basis of number of student users.

Table 1 indicates the distribution by subject matter of 523 distinct courses in mathematics in which the computer was used. These courses were reported on 434 responses for 348 different schools. The "miscellaneous" category includes responses that gave one or more catalog course numbers, but no clue as to content, as well as some "all math courses" responses with no specifics provided. Each such response was counted as one course. For purposes of this tabulation, numerical analysis was considered mathematics, but programming and computer science were not.

Additional information gleaned from the survey, broken down by subject matter, is detailed in the next three sections of this report.

TABLE 1
Computer Use by Course Content

Subject	Number	Percent
Calculus	142	27
Statistics and/or Probability	128	24
Numerical Analysis or Num. Methods	73	14
Pre-Calculus (algebra, Trig., etc.)	51	10
Linear Algebra	29	6
Differential Equations	23	4
Finite Mathematics	21	4
Liberal Arts Math.	12	2
Business Math.	10	2
Operations Research	8	2
Teacher Education	7	1
Abstract Algebra, Number Theory, etc.	7	1
Miscellaneous	12	2
TOTAL	523	

COMPUTER USE IN CALCULUS

Of the 141 individuals reporting on their use of computer-based materials in the teaching of calculus, only 31 (22%) made use of commercially published books or manuals which have a pronounced computer orientation. (Materials intended solely for teaching programming are not included here.) Nine of the 31 were using, or had used, Stenberg-Walker (CRICISAM); eight were using Dorn-Bitter-Hector; five Leinbach; four, Christie (EDC); two, Allen-Wing; and one each Kreider-Norman, Lynch-Ostberg-Kuller, and Schreiner. (See Section V for references.) In most cases, the numbers above include the school of origin of the material. While the CRICISAM material was in first place, and is known to have been used in many more schools, several of the respondents indicated that it had been, or definitely would be, dropped.

Fully 100 of the respondents used computer-based materials in the form of course notes, laboratory manuals, or supplements which they themselves had authored. The questionnaire asked if the respondents would be willing to share their materials with others, and some 21 of these seemed to have something of substance they were willing to share.

The patterns of computer use in calculus, as reflected in our survey, confirm the observations of Garland (AMS-MAA, 1975). Our Committee endorses the Garland report as accurately reflecting the state of the art.

Sixty percent of our 142 respondents viewed their computer usage as fully integrated into the calculus course, while 40% considered it only supplementary. On the matters of mode and language, there were some differences from the overall picture reported above. Fifty-nine percent used timesharing only, 27% batch only, and 14% both. For all users, these percentages were 46%, 24%, and 30% respectively. Note that timesharing is available to three-fourths of all users, and is perhaps more likely to be used in a lower division course. Fifty-six percent of the calculus respondents used BASIC, 40% FORTRAN, 12% APL and 13% other languages. (Obviously, many schools used more than one language.) The most significant difference from the overall figures is that FORTRAN is less popular in calculus.

COMPUTER USE IN STATISTICS

Computers in statistics courses appear to be used mainly in two areas: calculation, and data analysis. For both of these uses, computer software is very helpful. This explains why 83% of the respondents who use the computer in statistics classes use software of some kind, while only 42% use published or unpublished books, notes, or manuals. Other common computer uses were the preparation of graphical displays of data such as histograms, and simulation of elementary concepts such as the Central Limit Theorem.

Seventy-two percent of the computer-based materials used in statistics were developed at the respondents' institution. The breakdown of the materials used is summarized below:

- Published text 8%
- Unpublished notes 35%
- Internally developed software 55%
- Externally developed software 28%

The language chosen is most often FORTRAN and the mode of operation more often batch than for other mathematics courses. This is due to the orientation of most of the software used. These results from the survey are summarized below:

Mode		Language	
Time-sharing	43%	FORTRAN	50%
Batch	42%	BASIC	31%
Both	14%	APL	14%
		PL/I	4%
		Others	1%

The following table indicates the software packages reported in use by more than one respondent.

TABLE 2
Statistical Software Packages

Name of Package	No. of users
Statistical Package for the Social Sciences (SPSS)	7
Statistical Analysis System (SAS), N.C. State University	6
EASYSTAT, Georgetown University	5
Biomedical Computer Programs (BMD)	4
Tanis-Dershem, Hope College	4
STATPAC, Utah State University	4
OMNITAB, University of Texas	3
MINITAB, Penn State University	2

There is no lack of interest in the use of the computer in teaching statistics. Both the value and the feasibility of such use is widely recognized by instructors. The survey, however, indicates that this use has resulted in much duplication of effort, with many faculty members generating their own class notes and software, and not making use of the many materials that have already been developed elsewhere. The reasons for this are that the materials have been poorly marketed, resulting in a low awareness level, or, that they have not been responsive to the needs of the faculty who teach the statistics classes.

We believe the former is the case with the software, since much of the software developed internally at institutions duplicates the capabilities of available packages which are transferrable and flexible enough to be used in most contexts. But in most cases, these packages go unused because the faculty member is either not aware that they exist, or does not know how to go about having them implemented on the local computing system. The faculty member therefore develops his or her own inferior software, or does without.

Published materials, on the other hand, have been marketed through publishers and hence have had wide exposure to faculty members teaching statistics. The bibliography (Section V) indicates that there has been no lack of such materials. However, the survey indicates almost no use of any of these materials outside of the authors' institution. These published texts and manuals seem to have been judged unsuitable for classroom use by their intended audience. The reason for this may be that teachers of statistics differ greatly in the extent to which they wish to involve the computer in their classes, and, as mentioned above, there is no widely accepted standard in the software to be used. The published materials produced thus far have reflected the authors' views of the extent of computer involvement, and have specified the use of particular software, allowing for little flexibility in these areas.

Therefore, there are two areas that need attention before the situation in statistics improves. First, more faculty need to become aware of software packages that are available, and how these packages can be implemented in the classroom. Second, texts and exercise manuals need to be developed which satisfy the needs of a wide spectrum of potential users.

COMPUTER USE IN OTHER MATHEMATICS COURSES

Table 1 above indicates that computer use in mathematics courses other than calculus and statistics is rather scattered. As explained above, the Committee has not considered it necessary to study computer use in numerical analysis, which is surely more widespread than the survey shows. In this section we record some observations about the responses in each of the other areas.

Precalculus Mathematics

This category probably includes a lot of different types of courses, some intended as preparation for calculus, others teaching basic skills in algebra or arithmetic, but not intended to lead to higher courses. About half of the respondents were using CAI, probably in the form of remedial drill. There may be a legitimate role for well-designed drill programs in basic skills, to relieve instructors of time pressures and boredom.

Timesharing users outnumbered batch users 4 to 1, and BASIC outnumbered FORTRAN about 2.5 to 1. In some of these courses, a conscious objective was to introduce the student to the computer. Thus, getting the student to run some kind of program was more important than the particular topic being studied. There were some reports of use of the CRICISAM book by Feng and Stenberg (see Section V for reference), but the overwhelming majority used unpublished notes, mostly their own.

Linear Algebra

As in other areas, most instructors used their own notes. There were three users of McLaughlin, one each of Williams and Stenberg-Ducharme (see Section V for reference). Batch and timesharing were used about equally, as were BASIC and FORTRAN.

Differential Equations

The pattern here with respect to mode, language, and materials was essentially the same as with linear algebra. There were four users of Ziebur, and one of Hull (see Section V for reference). The numerical aspects of both linear algebra and differential equations are often included in numerical analysis courses, and many mathematicians consider that to be sufficient. On the other hand, a small but possibly growing number consider it short-changing the student to present a course in one of these areas without mentioning numerical methods, since most practical applications of both subjects are now carried out with the aid of computers.

Finite Mathematics

This is a subject that was essentially created by the classic text by Kemeny, Snell, and Thompson, and is now fairly popular as an elementary level, usually terminal, course. The usual ingredients are set theory, logic, finite probability, matrix algebra, and applications to linear programming and two-person games, all treated on a very elementary level. Where our respondents failed to give explicit course titles, it was difficult in many cases to distinguish between this type of course and more ambitious courses in linear programming and game theory, or in operations research. Nevertheless, it is clear that computer use is beginning to appear in the elementary course. (As with numerical analysis, it is essential in the more advanced courses.) The pattern of use, modes, languages, and materials was similar to that for linear algebra and differential equations. One book in this area has just been published (Dorn-McCracken) and another (Williams) is about to be (see Section V for reference).

Liberal Arts Mathematics

Probably no two of these courses are alike, each depending on the personality and interests of the instructor, on the text, and on the professed purpose for having such a course in the curriculum. Where the computer is used, its use is apparently similar to that in precalculus courses. Some respondents reported using the text by K.J. Smith (see Section V for reference), which contains a chapter on computers and their uses.

Business Mathematics

A few instructors in this area seem to be trying to give future businessmen a little hands-on computer experience. This may represent a new emerging trend.

III. PROSPECTS FOR THE FUTURE

The introduction of computer-related materials into undergraduate mathematics education, which began at a very slow pace, may accelerate noticeably in the near future. An important component of the force producing this acceleration is the current job market for students of mathematics, which is putting pressure on mathematics departments and professional organizations to change traditional patterns of education in the direction of more marketable skills. Perhaps a smaller component, but also important, is the fact that the results of many and varied experiments with computer use are now available, or are becoming available, as published or unpublished text materials and software. The importance of CONDUIT in sifting the wheat from the chaff, and in spreading the word about quality materials and software is clear. We expect that more information about computer-related ideas and materials will appear in the major journals. An important job for the Mathematics Advisory Committee will be to find ways to stimulate this flow of information to approach its recognized potential.

A number cf technological developments are affecting and will continue to affect future trends. The widespread availability of calculators (and anticipated availability of low-cost programmable calculators) will, on the one hand, stimulate interest in numerical solutions to "real world" problems in mathematics classes, and on the other hand, divert attention away from using large, fast, expensive computers for routine small-scale computations. Available inexpensive minicomputers with interactive terminals, plus existing or anticipated sound text materials, plus some display of leadership from "prestige" schools, will probably extend computer use in mathematics courses to essentially every campus. It will also enhance use on campuses where mathematics students now compete for scarce or expensive time on large machines with research, administrative, and computer science users. Inexpensive graphics terminals and stand-alone portable computers with graphic display should also contribute to this trend, as well as opening up new possibilities for real-time classroom use. However, all such exciting possibilities may be slowed down by current economic conditions. It seems clear that the hardware will be developed and that costs will decrease. It is not clear that development funds (public or private) will be available for educational applications. Whether rapidly (funded) or slowly (unfunded), we see an increasing adaptation of the educational process to an appropriate mix of use of calculators, minicomputers, improved terminals, and larger, more conventional computers.

While much of the use of the computer in statistics classes to date has been as a calculator, the availability of electronic desk-top and hand-held calculators has made the computer expensive and clumsy in such a role. In the future, more emphasis will be placed on the use of the computer for data analysis, graphical analysis, and simulations. The development of computer networks will help to make data bases available to more campuses for data analysis.

Similarly, while more instructors in calculus are discovering the value of integrating numerical computation into the traditional course, they are also going to discover that much of this computation can be done with the calculators their students already own and know how to use. The availability of sound textbook support (McCarty, see Section V) will hasten this discovery. In the short run, there may be a temptation to "choose" between calculators and computers, and economics may force the choice of the former. Eventually, the widespread use of calculators may enhance the development of instructional computer use by: (a) making it much easier to "get started" on algorithmic computation; (b) making it more natural to use numbers routinely in mathematics courses (strange as that may seem to a nonmathematician); and (c) identifying more clearly the limits of hand computation and the need for computers beyond those limits. McCarty notwithstanding, even problems in freshman calculus can get out of hand. Beyond matters of simple arithmetic, there are also important roles for graphics, array manipulation, symbol manipulation, tutorial interaction, and simulation that will not be displaced by calculators.

Developers of more sophisticated hardware and software are enthusiastically predicting dramatic effects on, and changes in, the teaching of mathematics, especially in view of decreasing hardware costs. For example, potential uses of the PLATO system for college teaching were recently presented to the American Mathematical Society [C.S. Weaver, "PLATO Elementary Mathematics and College Teaching", Notices A.M.S. 23 (1976) A-226, Abstract 731-96-1; L.V. DiBello, "The PLATO Community College Math Project," Notices A.M.S. 23 (1976), A-227, Abstract 731-98-3]. The most important feature of the PLATO system, developed at the University of Illinois, is its sophisticated and flexible graphics terminals, many of which can be supported by a single large computer. A great deal of courseware for the PLATO system has been developed and tested in tens of thousands of classroom hours at all grade levels, from elementary through college. There is little doubt that useful and exciting things could be done with PLATO at the college level. Weaver's paper, however, provides no cost estimates beyond expressing the conviction that "within five to ten years inexpensive machines with good graphics, large amounts of memory and computing power and simple, powerful programming languages will be widespread" (quoted from a preprint of the paper). Given foreseeable economic conditions on college campuses, we think that his prediction is much too optimistic, even if *a favorable cost/benefit ratio can be* established for college-level instruction.

Another example is provided by the MACSYMA system, a symbolic computation system developed by Project MAC at the Massachusettes Institute of Technology. One of its developers, P.S. Wang, recently reported to the American Association for the Advancement of Science on an experimental calculus course using symbolic computation ["Implications of Symbolic Computation for the Teaching of Mathematics," preprint; also submitted to CCUC/7]. Wang provides some details of MACSYMA: it lives in a PDP-10 with 512K words of memory; the system occupies 175K words, including 15K words of working space for the first user; and each additional user needs another 35K words for data and work space. A respondent to our survey, also at MIT, tempers his enthusiasm about the potential of symbolic computation with the observation that it currently costs about $25 per terminal hour. In spite of the interest generated by the MIT experiment, we believe that the educational benefits of symbolic computation are overstated by its proponents, and would remain so even if the costs dropped dramatically.

Another direction of interest for future development is at the other end of the scale: How can one get maximum educational benefit out of existing hardware/software without spending more money? One special aspect of this question concerns the primitive keypunch/card reader/small computer/line printer combination found on many campuses, and which may not be upgraded for years for lack of funds. The situation is not very different on many large campuses with large, fast computers, where the facilitiy may be shared with research and administrative users, and where educational computing may be relatively inefficient (as compared with a dedicated, timesharing, minicomputer). Another recent report to the American Mathematical Society [D. A. Smith, "A no-programming approach to computer use in mathematics courses," Notices A.M.S. 23 (1976) A-226, Abstract 731-98-1] presented an experiment now being tried on two campuses to get more mathematical education out of less time and effort, by people and computer, by using a packaged, general purpose, recursive sequence tabulator. The same author is also working on a program to produce low-cost line printer pictures of surfaces in space for students of multivariable calculus.

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 transferrable, 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.

IV. RELEVANT LITERATURE

JOURNALS

The actual or potential usefulness of each of the following journals is discussed above in Section I. Abbreviations in parentheses are used in the bibliographies below to indicate sources of reviews.

American Mathematical Monthly (AMM)

American Statistician

Creative Computing

Educational Studies in Mathematics

Journal of the American Statistical Association (JASA)

Mathematics Magazine

Mathematics Teacher (MT)

Notices of the American Mathematical Society (NAMS)

SIAM Review

Two-Year College Mathematics Journal (TYCMJ)

CURRICULUM

See Section I. for additional comments on the following materials.

Recommendations for an Undergraduate Program in Computational Mathematics, CUPM, May, 1971.

Recommendations on Undergraduate Mathematics Courses Involving Computing, CUPM, October, 1972.

A Compendium of CUPM Recommendations, CUPM, 1975. Includes the previous items and the 1965 GCMC report. Telegraphic review: AMM 83 (1976) 73.

Proceedings of a Conference on Computers in the Undergraduate Curricula (CCUC), University of Iowa Computer Center, annual proceedings beginning 1970. The quality of the mathematics sections of these conferences started high but has generally declined.

V. INSTRUCTIONAL MATERIALS FOR MATHEMATICS

□□CONDUIT REVIEW OF MATERIALS

The Mathematics Advisory Committee has sought to identify computer-based instructional materials, published or unpublished, for the full range of courses normally taught to undergraduates in departments of mathematics and/or statistics, with the exception of courses in numerical analysis, computer science, programming, or other "traditional" areas for computer use, in which the patterns of use and supporting materials are already established. We have attempted to acquire and screen everything that looked promising, on the basis of presentations at meetings, rumors, conversations with authors, and any other sources of information, and to submit to formal review all the items that still looked promising after first inspection. We have attempted to assign highest priority to the areas of greatest activity, but this has not always been possible, for a number of reasons: unavailability of materials known to exist, mismatch between "activity" and "materials production", different patterns of development in different areas, and so on.

Early in the development stage, much of the materials in mathematics (as opposed to statistics, and in contrast to other disciplines) centered around short, student-written programs, and thus did not involve software packages that needed to be moved. The Committee therefore concentrated on supporting text materials. It is not possible for CONDUIT to review every commerically published (or publishable) text using computers, so some choices have had to be made. In calculus, for example, we have elected to review two of the newer books (Leinbach, Smith) that appear to be flexible and generally useful, but not their slightly older counterparts (e.g. Dorn-Bitter-Hector, Allen-Wing) which may be better known and already subjected to other reviews. We have also elected not to review Schreiner because of its close tie to a particular hardware/software configuration at the University of Illinois. We have further declined to review full-scale calculus texts, such as Henriksen-Lees and Lynch-Ostberg-Kuller. Software packages of some value in mathematics (in contrast to most of the early attempts) are beginning to become available in greater numbers, and thus the Committee's reviewing efforts will probably be concentrated much less on published textbooks in the future.

In the area of statistics, represented on the Committee only since 1974, software packages have been available and in widespread use for some time. Our objective here has been to concentrate on materials with a valid pedagogical function in statistics courses as typically taught in undergraduate mathematics departments, avoiding duplication of efforts by our colleagues in the social sciences, and also avoiding packages designed for the researcher. One package was rejected by reviewers on the grounds that it was too research-oriented and not well-suited for instructional use.

The committee has also declined to review software packages which are properly classified as "systems" rather than as "instructional packages". Included in this category are the IMP system (and its relatives) developed at the University of Texas and the MACSYMA system developed at MIT.

COMPUTER-BASED MATERIALS OF INTEREST TO MATHEMATICIANS

The following materials have been identified as having potential for instruction in mathematics. 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 Section IV. Most reviews in the Monthly (AMM) are "telegraphic reviews", consisting of complete bibliographic information and brief comments.

CALCULUS

Allen, Jr. R.C., and Wing, M.G., Problems for a Computer Oriented Course. Prentice-Hall, 1973.
This unit 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.

Bogart K., and Vitale, M., The Calculus of Population. Project COMPUTe, Dartmouth College, Hanover, New Hampshire.
Short text on calculus of elementary functions; motivated by problems in population growth and supported by computer applications.

Christie, D., Garfunkel, S., et al., Computer and Laboratory Calculus. CALC Project, Education Development Center, Inc.
Use reported by 4 respondents to CONDUIT survey.

Computer Laboratory Manual for Calculus. Department of Mathematics, Lakehead University, Canada (unpublished).

Dorn, W.S., Hector, D.L., and Bitter, G.G., Computer Applications for Calculus. Prindle, Weber, and Schmidt, 1972.
This text contains many possible applications of computing in calculus. It 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. AMM 80 (1973) 103.

Garland, S.J., (ed.), Calculus and Computing. American Mathematical Society and Mathematical Association of America, 1975.
This pamphlet presents a current state of the art report for this area, plus case studies from nine different schools, sample problems, help on getting started, and a bibliography similar to this one.

Hamming, R.W., Calculus and the Computer Revolution. Houghton Mifflin, 1968.
This text should be required reading for instructors, but it 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. Worth Publishers, 1970.
This integrated calculus text with numerical applications is appropriate for honors students. AMM 78 (1971) 556-557.

Horn, R., Notes for a Calculus Computer Laboratory. Department of Mathematical Sciences, Johns Hopkins University (unpublished).

Hubbard, B., and Rheinboldt, W., Computer Calculus Laboratory Manual. Umporium, University of Maryland.

Kreider, D., and Norman, R., Calculus. Project COEXIST, Dartmouth.

Lax, P.D., Burstein, S.Z., and Lax, A., Calculus with Applications and Computing. Vol. 1. Springer-Verlag, 1976 (to appear).
This book represents a restructuring of the calculus course as an "introduction to applied mathematics". The appendix contains FORTRAN solutions to several problems.

Leinbach, L.C., Calculus with the Computer: A Laboratory Manual. Prentice-Hall, 1974.
This student-oriented manual is appropriate to supplement any calculus course, with appendices on BASIC and FORTRAN and a solutions manual. AMM 81 (1974) 190.

Love, W., A Computer Manual for Calculus. Department of Mathematics, University of North Carolina at Greensboro (unpublished).

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

This is an ambitious calculus text with an appendix on computer applications and numerical methods. AMM 80 (1973) 1082.

McCarty, G., Calculator Calculus. Page-Ficklin, 1975.
This text provides 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. It 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.

McNeary, S.S., Introduction to Computational Methods for Students of Calculus. Prentice-Hall, 1973.
This hardcover text for a course could be used in parallel to or following second semester calculus. The programs use FORTRAN. AMM 80 (1973) 962.

Sadler, W., Calculus: A Modeling Approach. Department of Mathematics, University of Wisconsin at Waukesha (unpublished).

Schreiner, A., Computer Calculus. Stipes Publishing Co., 1972.
This ambitious laboratory manual for a course at the University of Illinois is somewhat tied to the Illinois hardware and software and uses BASIC.

Smith, D.A., Interface: Calculus and the Computer. Houghton Mifflin, 1976.
This unit consists of a 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.

Stenberg, S., and Walker, R.J., Calculus: A Computer Oriented Presentation. Center for Research in College Instruction of Science and Mathematics (CRICISAM), Florida State University, Tallahassee, Florida, 1968.
This integrated course presents a nontraditional ordering of topics. It has been widely used for a number of years, less so now. Experience suggests it is too difficult for average students. Related publications include: AMM 78 (1971) 284-291, TYCMJ (Fall 1971) 51-54.

Strand, A., Calculus: A Computer Oriented Presentation. Department of Mathematics, Colgate University (unpublished).

STATISTICS AND PROBABILITY

Afifi, A., and Azen, S., Statistical Analysis: A Computer Oriented Approach. Academic Press, 1972.

For advanced undergraduate or graduate courses; this text emphasizes applied statistics techniques and assumes the availability of a local statistics software package. JASA 69 (1974) 279, AMM 80 (1973) 462.

Alluisi, E., Basic FORTRAN for Statistical Analysis. Dorsey Press, 1967.
Supplementary text for a computer lab to a statistics course.

Barr, A., and Goodnight, J., Statistical Analysis System (SAS). Department of Statistics, North Carolina State University.

Blackman, S., and Goldstein, K., An Introduction to Data Management in the Behavioral and Social Sciences: The Use of Computer Packages. Wiley, 1971.
A handbook in the use of statistical packages.

Brandt, S., Statistical and Computational Methods in Data Analysis. American Elsevier, 1970.
This text uses fairly rigorous treatment of data analysis. No exercises but some well-written FORTRAN programs are included in the text. AMM 78 (1971) 1044.

Bulgren, W., A Computer Assisted Approach to Elementary Statistics: Examples and Problems. Wadsworth, 1971.
This exercise manual contains Monte Carlo experiments to be conducted by computer and assumes a knowledge of FORTRAN. AMM 81 (1974) 424.

Burford, R., Statistics: A Computer Approach. Charles E. Merrill Publishing Co., 1968.
Intended for a course in elementary statistics for students of business and economics; contains flow-charts and FORTRAN program segments.

Clark and Hunt, Laboratory Manual: Introduction to Business and Economic Statistics with Computer Augmented Exercises. Southwestern Publishing Co.
Use reported by one respondent to CONDUIT survey.

COSAP. Computer Center, Lawrence University.

Dershem, H., Computer Exercises for Elementary Statistics. Holland, Michigan. Department of Mathematics, Hope College. Modified under Project COMPUTe, Dartmouth College, Hanover, New Hampshire, 1975.
A package consisting of a manual of exercises, thirty subprograms in FORTRAN or BASIC, and various data sets for use with a pre-calculus statistics course.

Elementary Interactive Statistical Package. North Carolina Educational Computing Service.

Freiberger, W., and Grenander, U., A Short Course in Computational Probability and Statistics. Springer-Verlag, 1971.
This set of lecture notes is intended for a graduate course; numerous APL programs are included. JASA 67 (1972) 954, AMM 79 (1972) 428.

Gilbert, N., Statistics. Saunders, 1976.
From an ad in AMM: Descriptive, inferential, and nonparametric statistics for non-math majors. Computational exercises using computer programs provided on punched cards with accompanying manual.

Gray, A., and Ulm, O., Elementary Probability and Statistics with Computer Applications. Glencoe Press, 1973.
Intended for a pre-calculus course; some programs in BASIC included.

Herum, G., Elementary Statistics. Iowa City, Iowa: Regional Computer Center, University of Iowa.
Multilithed course notes and associated software for a computer-oriented course.

Hodges, J.L., Krech, D., and Crutchfield, R.S., STATLAB: An Empirical Introduction to Statistics. McGraw-Hill, 1975. AMM 83 (1976) 77.

Hurst, R., STATPAC. Department of Applied Statistics, Utah State University.

Kirch, A., Introduction to Statistics with FORTRAN. Holt, Rinehart and Winston, 1973.
This text is intended for a pre-calculus course and contains many well written illustrative programs as well as an appendix of useful subprograms. AMM 81 (1974) 318.

Kirschenbaum, J., STATCARD: A Computer-Mediated Instructional Package for Introductory Statistics. Fullerton, California: Department of Psychology, Fullerton College.
Package is in a state of development.

Klecka, W.R., Nie, N.H., and Hull, C.H., SPSS Primer. McGraw-Hill, 1975.
This is a good handbook for courses using SPSS. See also Nie, et al., below.

Koh, Y. O., TUTSTAT-II. University of Nevada System Computing Center, Reno Nevada.
Powerful and easy-to-use package of BASIC programs with excellent manual, for the sophisticated user. No prior experience with computers necessary. Not well suited to classroom use, but a viable research tool for the person having completed one or more statistics courses.

Kossack, C.F., and Henschke, C.I., Introduction to Statistics and Computer Programming. Holden-Day, 1975.
As an introductory statistics text for students of social sciences, this text includes three chapters on FORTRAN and numerous FORTRAN programs to carry out computational procedures.

Lohnes, P., and Cooley, W., Introduction to Statistical Procedures: With Computer Exercises. Wiley, 1968.
This text is intended for a course in applied statistics for undergraduate and graduate students in the behavioral sciences and education. It contains many exercises and eighteen useful FORTRAN programs. JASA 65 (1970) 997.

Milton, R.C., and Nelder, J.A., (editors), Statistical Computation. 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.

Nie, N.H., Bent, D.H., and Hull, C.H., SPSS: Statistical Package for Social Sciences. Second ed., McGraw-Hill, 1975.
This is a reference manual for SPSS as well as for the statistical techniques available with the package. AMM 83 (1976) 77.

Novick, M.R., Bayesian Computer-Assisted Data Analysis. The American College Testing Program, Iowa City, Iowa.
Package is in a state of development.

Ryan, R., and Joiner, B., Minitab II. University Park, Pennsylvania. Statistics Department, Pennsylvania State University.
As a package intended for pre-calculus statistics courses, this system contains computational, plotting, and simulation routines with extensive error checking and diagnostics; it is available in transportable form.

Scalzo, E., and Hughes, R., Elementary Computer-Assisted Statistics. Petrocelli/Charter, 1975.
This is an elementary statistics text with accompanying BASIC programs to accomplish computational tasks.

Snell, J.L., Introduction to Probability Theory with Computing. Prentice-Hall, 1975.
This introductory probability text makes use of BASIC programs to illustrate concepts by simulation. AMM 82 (1975) 1031.

Spitznagel, E., untitled text, subroutines, and data, Department of Mathematics, Washington University, St. Louis, Mo.

Sterling, T.D., and Pollack, S.V., Introduction to Statistical Data Processing. Prentice-Hall, 1968.
A good description of the capabilities of computers in relation to statistics. Uses the computer for data analysis and graphical displays. Somewhat dated with respect to hardware description.

Tanis, E., Laboratory Manual for Probability and Statistical Inference. Holland, Michigan. Department of Mathematics, Hope College.
This package consists of a manual of exercises and software for plotting and simulation.

Tucker, A.B., EASYSTAT. Academic Computer Center, Georgetown University, Washington, D.C.

Weed, H., Descriptive Statistics. Project COMPUTe, 1973.
From a COMPUTe abstract: This unit supplements student textbooks on elementary statistics and probability, discusses methods and their intelligent uses, and introduces statistical calculations using the computer.

LINEAR ALGEBRA

Fraleigh, J.B., A Programming Computer Supplement for Beauregard and Fraleigh: A First Course in Linear Algebra. Department of Mathematics, University of Rhode Island, 1973.
This package consists of 11 projects which parallel the development of topics in the Beauregard-Fraleigh text, to be done in part with BASIC programs provided, and in part with student-written programs. The package is usable to supplement other linear algebra texts as well. (see next listing also)

Fraleigh, J.B., A Short Computer Supplement to Beauregard and Fraleigh: A First Course in Linear Algebra. Department of Mathematics. University of Rhode Island, 1974.
A second supplement to the Beauregard-Fraleigh text using the supplied BASIC programs only for those instructors who prefer their students not learn to program.

Goult, R.J., et al., Computational Methods in Linear Algebra. Halsted Press, 1974. AMM 83 (1976) 74.

Kolman, B., Introductory Linear Algebra with Applications. Macmillan, 1976.
From an add in AMM: "The use of computers in linear algebra is briefly explored in the Appendix, which includes 53 computer projects of varying levels of difficulty, comments on APL plus BASIC."

McLaughlin, D.E., A Computer Oriented Course in Linear Algebra. CONDUIT, 1974.
This package consists of a textbook and FORTRAN subroutines for reduction to echelon form, Gram-Schmidt process, characteristic polynomial, and simplex algorithm. It 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. McGraw-Hill, 1974. AMM 81 (1974) 926.

Stenberg, W., and Ducharme, R.G., Computer Oriented Linear Algebra. CRICISAM.
Some use reported by CONDUIT survey respondents. One listed publisher as Holt-Rinehart-Winston. Described in paper contributed to 1973 Missoula conference; see Abstract 706-98-2, NAMS 20 (1973), p. 1-546.

Williams, G., Computational Linear Algebra with Models. Allyn and Bacon, 1975.
This text covers standard topics plus numerical methods with an unusually broad array of applications. It consists of about 20 BASIC programs and accompanying computer exercises are provided in an Appendix. AMM 82 (1975) 543.

DIFFERENTIAL EQUATIONS

Bellman, R., and Cooke, K.L., Modern Elementary Differential Equations, Second Ed. Addison-Wesley, 1971. AMM 76 (1969) 102-103 and 79 (1972) 544.

Braun, M., Differential Equations and their Applications. Springer-Verlag, 1975.
This modern, complete text in ODE's presents many interesting applications. FORTRAN and APL programs illustrate numerical solutions. An appendix gives a brief introduction to APL. AMM 82 (1975) 1029.

Derrick, W.R., and Grossman, S.I., Elementary Differential Equations, Second Ed. Addison-Wesley, 1971. AMM 76 (1969) 102-103 and 79 (1972) 544.

Hull, T.E., Numerical Integration of Ordinary Differential Equations. MAA-CUPM, 1966.
Brief supplement for an ODE course. AMM 75 (1968) 699.

McLaughlin, D.E., Numerical Solution of Ordinary Differential Equations. Regional Computer Center, University of Iowa, 1973.
These multilithed course notes are intended as a computer-oriented supplement to a standard differential equations course.

Ziebur, A.D., Topics in Differential Equations. Dickenson, 1970.
This document 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

Dorn, W.S., and McCracken, D.D., Applied Finite Mathematics and Computing. Wiley, 1976.
In this text computer use is fully integrated using BASIC.

Williams, G., Finite Mathematics with Models. Allyn and Bacon, 1976 (to appear).

NUMBER THEORY

Kirch, A.M., Elementary Number Theory: A Computer Approach. Intext, 1974.
This solid text applies the computer in expected ways. The programs are in FORTRAN. AMM 81 (1974) 926.

Malm, D.E., A Computer Laboratory Manual for Number Theory. Project COMPUTe, Dartmouth, 1975.
From a COMPUTe abstract: Intended to supplement a text in number theory, arranged by topic. For each topic, includes description of concepts; experiments for before, during, and after study of topic; references.
Instructor's manual, approximately 40 programs in BASIC.

LIBERAL ARTS MATHEMATICS

Dorn, W.S., and Greenberg, H.J., Mathematics and Computing: with FORTRAN Programming. Wiley, 1967.
Intended for a pre-calculus, 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. Brooks/Cole, 1973, Second ed., 1976.
Use reported by some respondents to CONDUIT survey. AMM 81 (1974)

SYMBOLIC LOGIC

Moor, J., and Nelson, J., BERTIE. Project COMPUTe, Dartmouth College, 1975.
This package consists of an interactive BASIC program and a student/instructor manual. It is intended to teach the skills needed for natural deductive derivations and to enhance students' ability to write and recognize well-formed formulas. It uses the Gustason-Ulrich system of natural deduction.

PRE-CALCULUS MATHEMATICS

Burrowes, T.C., and Burrowes, S.K., Elementary Functions: An Algorithmic Approach. Intext, 1974.
From an ad in AMM: "The algorithmic approach refers primarily to the use of flowcharts as a teaching-learning tool. It does not presume any knowledge of computers or programming, nor does it require any computer involvement, although flowcharting exercises are provided for those who desire them, and programs that can be used as computational tools are included in an appendix."

Feng and Stenberg, Second Course in Algebra and Trigonometry. Center for Research in College Instruction of Science and Mathematics (CRICISAM).
Use reported by some respondents to CONDUIT survey.

Higgins, G.A., Jr., The Elementary Functions: An Algorithmic Approach. Prentice-Hall, 1974. AMM 81 (1974) 104.

Iverson, K.E., Algebra: An Algorithmic Treatment. Addison-Wesley, 1971. AMM 81 (1974) 420.