Conference Board of the Mathematical Sciences
Committee on Computer Education

RECOMMENDATIONS REGARDING COMPUTERS IN HIGH SCHOOL EDUCATION

Prepared with the support of the National Science Foundation

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Preface

The Conference Board of the Mathematical Sciences, its Council and several of its member organizations have for some years had a continuing interest in questions of computer education, and especially computer education at the secondary school level. As early as the Fall of 1967 a knowledgeable member of the CBMS Council estimated that high school courses on computers and computing already numbered in the hundreds, and that over 1,000 digital computers were by then being used by secondary schools or by school administrations. With such activities sharply on the rise, it was already clear that there would be rapidly mounting pressures on secondary-school teachers to teach something about computing, and that the character and quality of what was to be taught would depend heavily on the guidance and materials available to these teachers.

Prior to 1965 essentially no such materials were available, apart from private notes and commercially prepared computer manuals, from which little of pedagogical value has survived. In 1966 the first versions of two experimental high-school computer courses appeared, one [1] sponsored by the Commission on Engineering Education and the other [2] by the School Mathematics Study Group. Although these courses were intended to serve quite different purposes and followed sharply different approaches, both had academic and pedagogical value and both have since been modified and have continued to exert influence. By 1968 there had appeared a growing variety of efforts relating to high-school computer education sponsored by the National Science Foundation, the National Council of Teachers of Mathematics, the Association for Computing Machinery, the Association for Educational Data Systems, the U.S. Office of Education and other organizations.

At the January 1968 meeting of the CBMS Council, its Committee on New Areas in the Mathematical Sciences appointed a Subcommittee to study and make recommendations regarding a possible CBMS Committee on Computer Education. This Subcommittee met in May 1968 and drafted a report recommending the formation of such a Committee and the investigation of specific tasks. While the Committee was not to be confined to questions of high school computer activities, it was felt that these constituted an area of urgency where the Committee's initial efforts might well be concentrated. In response to this recommendation the CBMS Council at its meeting of August 1968 authorized the appointment of a Committee on Computer Education. The Committee was appointed that fall and has operated since 1969 under a grant from the National Science Foundation to make a study and recommendations concerning high school computer education.

This Committee, consisting of William F. Atchison, Edward G. Begle (Chairman), Sylvia Charp, William S. Dorn, David C. Johnson and Jacob T. Schwartz, has brought to the problems of computer education at the high school level an impressive concentration of expertise, knowledge and experience. As individuals, all have participated in one or more of such activities as the direction of major high school computer curriculum projects, the writing of textbooks involving computer use in high schools, the pre-service and in-service computer training of high school teachers and the supervision of computer education in large urban school systems. In addition, two are directors of computer centers at major universities, and several have played leading roles in the high school computer education projects of professional societies and non-profit organizations, including the National Council of Teachers of Mathematics, the Association for Computing Machinery, the American Federation of Information Processing Societies, the International Federation for Information Processing [3], the Association for Educational Data Systems, the Organization for Economic Cooperation and Development [4] and others.

The Committee would like to acknowledge its debt to numerous publications, background materials and special studies, only some of which are listed in the bibliography of the present report. A special acknowledgment is due the American Institutes for Research (AIR) and especially Mr. Charles R. Darby, Jr. of the Washington office of that organization for making available to the Committee the October 1970 pre-publication draft of AIR's extensive report to the National Science Foundation, *A Survey of Computing Activities in Secondary Schools* [5]. Mr. Darby was also helpful earlier in

briefing the Committee on the progress and preliminary results of that massive Survey. Using the AIR Survey as a guide, the Committee itself made or commissioned site visits to several areas of especially interesting or intensive high school computer activities, including the areas of New York City, Philadelphia, Minneapolis, Denver and San Francisco Bay.

The Committee owes particular thanks to Professor Richard Andree of the University of Oklahoma and Dr. George Heller of the Association for Computing Machinery, who made reports at a meeting of the Committee concerning the high school computer education activities of those organizations and offered other useful information and advice. The Committee is also grateful for special courtesies, information and materials to Mr. John Guerrieri, Jr. of the Data Processing Management Association, Dr. Carl Hammer of the Accreditation Committee of the Association for Computing Machinery, and Mr. Donald Lund of TIES (Total Information for Educational Systems).

Finally, the Committee would like to express its deep appreciation to the Office of Computing Activities of the National Science Foundation for the grant which supported the present study, and especially to Dr. Arthur S. Melmed and Dr. Andrew R. Molnar of that Office for attending several of the Committee's meetings and furnishing valuable information.

Edward G. Beg1e

April 1972 — Chairman, Committee on Computer Education

CONTENTS

1. A Summary of our Recommendations

In this section we summarize our recommendations concerning computer education in secondary schools. The recommendations themselves, in somewhat more detail, and our rationales for them, will be found in the later sections of this report.

For the most part, our recommendations are addressed both to the mathematical sciences community, urging that certain educational projects be undertaken, and to the National Science Foundation, urging financial support for them. A few, however, are concerned with the way a project should be conducted.

A_1. *We recommend the preparation of a junior high school course in "computer literacy" designed to provide students with enough information about the nature of a computer so that they can understand the roles which computers play in our society.*

A_2. *We recommend that the process of preparing the text materials for the above course be such as to provide wide and rapid dissemination of information about the availability and feasibility of the course.*

B. *We recommend that text materials for a number of other courses be prepared, including an introduction to computing, as a followup to the computer literacy course, some modules which integrate computing into high school mathematics courses, and other modules which utilize computers in simulating the behavior of physical or social phenomena and which enable the use of computers in the study of courses outside mathematics.* (Note: While materials exist for use in mathematics and science, the module-problem nature of the recommendation reflects a quite different approach for a more complete discussion see sections 4 and 5 of this report.)

C. *We recommend the development of special programs for high school students showing unusual aptitude and promise in computer science.*

D. *We recommend a major effort aimed at making vocational computer training more generally available and at the same time improving the quality of such training.*

E. *We recommend that the National Science Foundation provide financial support for the development of a variety of programs for the training of teachers and of teachers of teachers of high school courses involving computers.*

F. *We recommend the establishment of a clearinghouse for information about high school computer education.*

Now, let us suppose that the above recommendations are accepted and carried out. Any school wishing to use the resulting instructional materials to institute a new computer education program,or upgrade an existing one, will find it necessary to have access to a reasonably powerful computer. We have, however, made no specific recommendations in the present report regarding relatively inexpensive computers or time-sharing arrangements suitable for high school computer education purposes. The reason for this is that our committee feels that the technology of computer hardware production is changing rapidly at the present time and will continue to change rapidly over the next few years, and that this will have major effects in lowering the cost of computer hardware and the price at which commercial time-sharing service is available.

2. <u>A Universal Computer-literacy Course</u>

Computers now impinge in a very direct way on the lives of practically every citizen of this country. Computers compute gas bills, phone bills, and bank balances. Computers check income tax returns. Computers process the data from the decennial census.

Computers predict who will be elected. Computers print out monthly welfare checks.

Of course, computers do many other important things in our society. They are used to operate factories and oil refineries. They are used by businessmen to plan and supervise their business operations. They are used to keep track of the need for food, supplies, etc., of our armed forces. Without computers our moon landings would have been impossible. But the examples in the preceding paragraph indicate that computers have very direct impact on the average U.S. Citizen.

The average U.S. Citizen hasn't the foggiest idea of how computers work and how pervasive their influence actually is. Consequently, he has no idea of what to do when a computer system makes a mistake; he has no idea of how to vote on local, state, or national issues involving computers (e.g., the establishment of a national data bank); he is, in short, culturally disadvantaged.

It is therefore essential that our educational system be modified in such a way that every student (i.e., every prospective citizen) become acquainted with the nature of computers and the current and potential roles which they play in our society. It is probably too late to do much about adults, but it would be disastrous to neglect the next generations.

We therefore recommend that the National Science Foundation encourage and provide financial support for the preparation and periodic revision of at least one secondary school course in "computer literacy."

At a minimum, this course should:

a. Give the student enough understanding about the way the computer works to allow him to understand what computers can and cannot do. Wherever possible, this should involve at least a minimum of direct interaction with a computer, primarily (at this level) through the use of appropriately pre-programmed application packages.

b. Include a wide sampling of the ways in which computers are used in our society, with non-numeric as well as numeric applications. The impact of these various uses on the individual should be made clear.

c. Introduce the notion of an algorithm, and its representation by flow charts; where time allows and as equipment becomes available, discuss the manner in which algorithms are represented by programs and the way in which programs are executed by machines.

Since the course is intended for all students, the course materials may have to be prepared in two different formats: one for above-average students and the other for below-average students. The latter should contain more illustrative examples, and the former should penetrate more deeply into at least some of the topics.

We suggest that the course be designed for junior high school students.This is about as late as the requirement of specific courses can be insisted on by local school systems. Also, by grade eight, students will have been exposed to enough mathematics so that a reasonable variety of computer activities can be discussed meaningfully.

A course meeting two periods a week throughout the year or four periods a week for one semester should be sufficient to accomplish the purposes mentioned above.

Teachers' commentaries should accompany the course materials. In preparing these it should be kept in mind that the teachers of the course should ideally be drawn from many different subject matter areas.

Preparation of textual materials for the computer literacy course will net be enough. Wide implementation will depend upon dissemination of information as to its availability and, in particular, information about its feasibility and classroom effectiveness.

We therefore recommend that in preparing the computer literacy course the procedures used by the School Mathematics Study Group in its curriculum development projects be followed.

These procedures were designed to ensure three things simultaneously: that the texts be mathematically sound, that they be pedagogically sound, and that information about them be quickly and widely disseminated.

The first step in this procedure would be to appoint a planning and outlining group of approximately a dozen individuals consisting of experienced and respected classroom teachers and equally experienced and respected university and industry computer scientists. The first task of this group would be to meet together for a week or so to plan and outline in some detail the computer literacy course.

The next step is to choose a writing team. Like the outlining group, this writing team should contain a balance between experienced classroom teachers and experienced computer scientists. Also, the writing team should contain a substantial representation from the outlining group. (SMSG experience indicates that 12-15 is the optimal number for a writing team.) A six-week summer writing session should be sufficient for the preparation of a preliminary version of the text, as well as a teacher's commentary to accompany it.

This preliminary version should be given a thorough classroom tryout during the following school year. About a dozen locations should be chosen, scattered across the country. In each location, half a dozen or so volunteer schools should be located in each of which two or more volunteer eighth or ninth grade classes would be provided. A consultant from a nearby university or industrial computer laboratory should be provided to offer an inservice course meeting once a week, if necessary, for the participating teachers.

The final step would be for use feedback from this classroom experience, including comments both formal and informal from the teachers, in preparing a revised version of the text and teacher's commentary during the following summer.

The important features of the above program are, first, the inclusion of classroom teachers and computer scientists in substantially equal numbers and on an equal footing, and second, the geographically widespread tryout of the preliminary version of the text. The first is essential in order to ensure both the scientific and the pedagogical soundness of the text. The second is essential to provide widespread information about the text quickly. Local channels of communication about an educational innovation, which this text surely would be, seem to be surprisingly effective.

We note that this and other projects recommended in the present report intersect interests of several member organizations of the Conference Board of the Mathematical Sciences. Perhaps most directly involved is the National Council of Teachers of Mathematics, since high school mathematics teachers will evidently play a leading role in any effective implementation or high school computer education; and indeed the NCTM has already issued several publications in this regard, among them [6], [7], [8], [9]. The Association for Computing Machinery is now taking an increasing interest in high school computer education, especially through stimulating the formation of high school computer clubs; and the ACM has had a long-standing interest in the related matter of collegiate-level computing curricula [10], as has the Mathematical Association of America's Committee on the Undergraduate Programs in Mathematics [11]. In fact, all the CBMS organizations have some involvement with computers and hence a concern, more or less direct, for effective computer education. This is especially true not only of organizations like NCTM and ACM but also of organizations like the Society for Industrial and Applied Mathematics, the Institute of Mathematical Statistics, the Society of Actuaries, the Operations Research Society of America and The Institute of Management Sciences, where computers are of steadily increasing importance as a professional tool.

Finally, we emphasize that the preparation of curricular materials for high school courses involving computers is not to be viewed as a one-shot effort. The field of computer design and application is a fast-moving one; and as it develops, high school course-work on computers and their utilization will certainly need to be revised and up-dated.

3. Introduction to Computer Proficiency and Applications

It is our hope and expectation that substantial numbers of students, having learned something about the role of computers in our society, will wish to learn more about computers and, in particular, how they can be applied to their own particular interests.

We therefore recommend the preparation of an independent follow-up course to the basic computer literacy course designed to develop proficiency in the use of computers, particularly in the mathematical, physical, biological, and social sciences.

The language used should be BASIC, and the course should be devoted to a representative set of problems and the preparation of programs for their solutions. For the course to be successful it will be necessary to arrange for access to a computer. Two periods a week for a school year or four class periods a week for one semester could be allowed for this follow-up course. In preparing the teachers' commentary it should be kept in mind that, for some time at least, the teachers of the course will be mainly mathematics teachers.

We suggest that the preparation of text materials for this follow-up course be integrated with the preparation of text materials for the basic literacy course. Once the latter has been outlined, the same group, augmented with a few senior high school teachers and a few scientists, could outline the followup course. In order to adhere to the time schedule suggested above, a separate writing team would be needed; but the two teams should be located at the same spot for close liaison. Tryouts of the follow-up course could be carried out with the same students that tryout the basic literacy course, the latter being taught the first semester and the former the second.

4. Computers in Mathematics Courses

Curriculum materials which integrate computing into mathematics courses are presently available from a variety of sources (see [9]); however, they do not appear to have gained widespread adoption by schools. Some of the reasons for this relatively meager use of these materials are the lack of an efficient means for disseminating the materials and the lack of training for present and future secondary school teachers in the use of such computer-related materials. The former (dissemination of information) is discussed in Section 9 of this report while the latter (teacher training) is considered in Section 8.

Many of the already available computer-related curriculum materials are of high quality, and schools should be encouraged to make use of some of them in their mathematics program at the earliest possible time. It should be kept in mind, however, that to date few materials exploit the computer to anything like its fullest extent. Our Committee feels that it is best to realize the computer's potential with as little disruption as possible to the present curriculum.

We therefore recommend the development of short modules (or units) using computers in problem-oriented situations that emphasize the application of mathematics to the range of problems relevant to today's society.

Some specific suggestions of typical modules are given below. Each of these modules should address a specific problem from civics, biology, geography, etc. The module should discuss the assumptions necessary to formulate a reasonable mathematical model of the situation at hand. In this connection it is to be emphasized that the materials should start with the simplest possible assumptions that yield realistic results and should progress in stages to more and more sophisticated models. The teacher and/or student can then proceed through the module to the depth which is commensurate with his background and interest and the time available.

Following delineation of the basic assumptions and construction of the mathematical model, the module should guide the student towards development of an algorithm* for the solution of the model, the writing of a computer program for the algorithm, and an analysis of the solution or solutions in order to draw some qualitative conclusions about the nature of the problem and the solution. In many cases this analysis should lead to a re-examination of the assumptions and model, and to construction of a new, better and more realistic model.

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* In most cases the algorithm, although perhaps complex and tedious, will be rather straightforward.

The above guidelines imply that the modules will and should assume that the student has some proficiency in the use of a programming language, in most cases BASIC, before he begins work on the module, and that he has access to some computing facility. The required degree of proficiency will usually be that acquired in the BASIC programming course described in Section 3 of this report. Modules should be constructed in such a way that they can be profitably used with four or five hours of classroom instruct:ion, although a complete coverage of the most sophisticated model might require several weeks. The teacher can then use the module to the extent he wishes and time permits.

Both an Instructor's and a student's edition should be available, and the instructor's edition should be carefully keyed to existing courses and textbooks so that the module may be reasonably and profitably used with a minimal amount of disruption to the existing curriculum. Additional references that are readily available to secondary schools, e. g., *Scientific American* articles, should be included for: the ambitious student who wishes to investigate the topic further.

It is essential that a module be designed to lead quite naturally to a significant mathematical topic (statistics, probability, graphs, etc.), and that the module include material on this mathematical topic after proper motivation.

The hypothetical units sketched below will indicate the wide range of possibilities available.

a. Biology and Ecology: A game warden is in charge of stocking a lake with fish. During four months of the year fishermen remove fish from the lake. The following four months constitute a breeding period. Make some assumptions regarding (a) the percentage of the fish which are removed in fishing season and the pattern of removals, (b) the number of fish born per adult fish during breeding season, (c) the death rate of the fish. With these assumptions decide on a strategy for stocking the lake (when and how, much) to reach some objective. The objective may be to keep the fish population above a given number or to have the fish population fluctuate between two values.

Note that a unit of this kind makes natural the introduction of such notions as periodic motion, functions, rates of change, limits (if the fish population stabilizes), equilibrium. Stability, difference equations, etc. It also can lead into discussions of probability and stochastic processes.

b. Economics: A businessman buys raw materials and uses them to produce a product which he sells. For example, if fewer than 100 units of raw materials are purchased, each unit costs $2; if between 100 and 500 units are purchased, the cost is $1.50 per unit; and so on. Similarly, production costs and the selling price of the product also vary with the quantity produced or sold. Determine the quantity of raw, materials whose purchase maximizes profit.

Note that such a unit leads to consideration of functions, maxima and minima, derivatives, inequalities and, in the more sophisticated cases, linear programming.

c. Sociology and Civics: Consider the racial integration of an organization such as a police department. Collect data on (a) the present racial makeup of both the organization and the population from which new members are drawn, (b) the exit rate of members from the organization, (c) the growth rate of the organization, (d) recruiting policies and techniques, and so on. Determine a policy (growth rate and/or recruiting plan) to achieve a given level of integration (percentage of minority members in a given time).

Note that this unit leads to topics similar to those in Example a, above, i.e., functions, rates of change, limits, equilibrium, stability, difference equations and probability.

d. Medicine: Suppose two drug companies each announce the availability of a drug purported to cure the same disease. Company A announces that it has tested its drug on 20 patients in each of 1,000 locations and has effected 12 or more cures in 870 locations. Company B, on the other hand, has tested its drugs on 10 patients in each of 1,000 locations with 6 or more cures in 850 locations.

Which of the two drugs is more likely to cure a person with the disease? Note that this problem leads to a discussion of probability, in particular binomial trial experiments, and root finding.

e. Urban Planning: Suppose that during some time period one fraction of a vacant area in a city is used for residential housing, another fraction is used for commercial housing, yet another fraction is turned into parking lots, and the remainder continues to be vacant. Similarly, suppose that land presently used for residential housing is transferred into commercial, vacant and parking lots in some fixed way. Corresponding assumptions are to be made regarding the redirection of commercial property and parking lots to other types of usage. If that pattern of land reuse continues, what will the city be like in five years? Ten years? After a long period of time?

This problem leads into matrices and their manipulation, solutions of linear systems of equations, equilibrium, stability, stochastic processes, fixed point vectors and the like.

5. Computer Use in Science and Other Fields

While student-written computer programs appear to be the most profitable approach in mathematics courses (see Section 4, above), pre-packaged programs appear to hold the greatest promise in other disciplines. In these areas the emphasis is on the application itself rather than on the mathematical model of the process.

We therefore recommend that short modules (or units) concerned with simulating the behavior of physical or social phenomena be developed for use in physics, chemistry, biology, economics, business, and social studies classes.

Such modules should be accompanied by complete, running programs which can be used by a student who does not necessarily know how to write computer programs. Each module should carefully explain all of the assumptions underlying the simulation computer program. The module should be carefully keyed to existing courses and textbooks and should indicate precisely how the computer simulation aids in the course. Modules should require no more than one or two hours of classroom time but may require the student to use the computer for considerably more time. There should be ample reference material for further study, and both a teacher's and student's edition should be available. Computer programs should be completely self-contained, and the minimal computer configuration (memory required, subset of BASIC used in the program, etc.) necessary to run the simulation should be completely spelled out. Modules should simulate experiments which it would be impractical to carry out in a laboratory. For example, there is little value in simulating a simple pendulum, since one can easily be constructed and studied in a physics laboratory. On the other hand, sociological experiments are difficult if not impossible to study in a real-life form and are therefore best simulated on a computer. Examples can be found in the Huntington II Computer Project simulations developed at the Polytechnic Institute of Brooklyn.

Some examples of typical modules are given below.

a. Social Studies: Two opposing political groups take certain courses of action based on assumptions each makes regarding the other's anticipated action. The computer produces the public reaction (in terms of voting preferences, for example) to these actions, and a new course of action is selected by each group. Two students may take the roles of the two groups, or one student may take the role of one group while the computer plays the role of the other. Such a module should be designed not only to help the student understand the development of political strategies but to see some of the pragmatic aspects of such a strategy and the degree to which the options open to the strategist are restricted.

b. Biology: Suppose there are several species of wildlife some of which prey upon one another and some of which are sustained by the land. In the computer simulation the student changes hunting regulations, planting and harvesting policies for foliage, etc., and studies the effect of such decisions on the populations of the various species. In this way the student should come to realize which are the sensitive parameters in such an ecological system.

c. Economics: In a model of the national economy the student makes certain changes in the tax structure, government spending for defense and/or domestic use, interest rates, etc., and observes the impact of these changes on the national economy, i.e., consumer income and the like. Again the objective is to gain some intuitive understanding of the sensitive factors in an economy.

d. Ecology: In a model of the water system of a geographical region the student makes changes in waste disposal regulations for commercial firms, types of allowable home sewage disposal (e.g., outlawing kitchen disposals), minimal and average reservoir levels, etc., and observes the consequences of these changes on the cost and availability of water. Once more the objective is to determine what types of policies can have substantial effect on the factors of interest and to gain some intuitive feeling for the extent to which changes must be made in order to bring about a significant change in cost or availability.

6. Special Programs for the Gifted Student

Computer contact provides a very special opportunity for the gifted student, and many such students are strongly attracted, even fascinated, by this opportunity. The computer world is one of the few in which students can, even for short periods, personally control one of the most advanced existing items of scientific equipment. Talented students who become caught up in the computer world often develop rapidly to a really professional level, frequently outstripping their teachers and sometimes contributing in a significant way to current research efforts. Programs that put students of this kind into direct contact with college-level computer study and research can be quite valuable, especially in broadening the gifted student's view of the scope and goals of computer science.

We therefore recommend the funding of a variety of programs in computer science for the especially gifted high school student.

In particular, we suggest after-school and Saturday courses for students liVing in the vicinity of colleges and universities with strong computer science programs, and summer programs for gifted students from other areas.

7. Vocational Computer Training

We have indicated that more than a million workers presently find employment in one or another branch of the computer industry. This force is trained largely in commercial electronic data processing schools, some of dubious quality. Such private electronic data processing schools may have graduated as many as 100,000 students in 1971. These facts make clear the importance of the following recommendation.

We recommend a major effort aimed at making vocational computer training more generally available and at the same time improving the quality of such training.

Existing vocational-technological high schools, suitably strengthened, ought to play a central role in this effort; formal programs in programming and data processing ought to be organized in such schools.

Three quarters of the programmers employed in the United States work with the business-oriented COBOL language. Nevertheless, although there exist several useful learner's languages (such as BASIC) which provide introduction to the less used FORTRAN scientific programming language, there exists no introductory language related in the same way to COBOL. *It is desirable that the development of such a language be sponsored*. This language ought to be file oriented, and provide simplified facilities for handling all the main forms of commercially useful input-output equipment: cards, tapes, and rotating storage devices. Suitable curriculum materials, oriented toward commercial programming and relating appropriately to courses of high school level in bookkeeping, commercial arithmetic, and so forth, ought to be developed in connection with this "learners' COBOL language. Exposure to such a stepping-stone language would make it easier for the vocationally oriented student to absorb the additional training in full COBOL and in the commercially important operating systems needed to facilitate his or her absorption into the EDP industry.

Timeshared use of large computers is an effective and often inexpensive way of introducing large numbers of students to programming. However, the computing environment provided by a timesharing service differs significantly from that typical in commercial data processing, where bulky private data files maintained on dismountable storage media play an important role, and where modest stand-alone configurations greatly outnumber large centralized facilities. Vocational computer programs should, when possible, expose students not only to timeshared computing but to a computing environment more typical of the commercial world. Fortunately, the presently-considerable expense of providing this type of exposure should diminish considerably during the next few years, as more powerful and less expensive mini-computers become available. Mini-machines of the anticipated type will be near ideal vehicles for the study of the file-oriented "learners' COBOL" described above. Such machines can also serve to provide the hands-on experience needed by the future computer operator.

Inexpensive file input and storage peripherals, providing facilities of commercial type but at a lower level of performance, should be developed in the same period. The peripheral and storage device requirements of vocationally oriented computer programs can probably be satisfied by a judicious combination of

(i) small digital magnetic tape cassette recorders

(ii) flexible plastic disc magnetic storage devices

(iii) inexpensive input-output terminals.

Many of these components will probably be offered by commercial manufacturers within the next few years, but where necessary a few development efforts should be sponsored at universities. Computer and peripheral device development together may be expected to yield a reasonable mini-computer configuration which could be sold for under $2,000.

Experience with key-punch and other important forms of console input equipment should be provided, perhaps in the framework of the standard typing courses presently offered in high schools. Exposure to this type of equipment can considerably broaden the perspective of future employment for many students.

For this purpose, funds enabling high schools to acquire or rent modest amounts of key-punch or other specialized console equipment may be required.

8. Recommendations for Teacher Training

The computer is a valuable teaching tool, but it will be effective only if teachers are trained in its use. Moreover, it is the teachers, properly trained, who can convey to students the power of this tool and how to use it.

While there have been widespread improvements in the education of prospective teachers, training in the use of up-to-date technology is still not included in the curricula of most teacher training institutions. In addition, prospective teachers need an informed conception of the social .impact of the computer so that they in turn can help prepare their students to cope in a technological society. This cannot be taught in a single subject alone: it is a way of thinking that must be imparted in many courses.

Unfortunately, faculty members in most schools of education have themselves insufficient background in computer knowledge and are therefore not able to develop appropriate curricula. Where talent from other departments of the university, such as those of computer science, electrical engineering or mathematics, has been called upon for assistance, some progress has been made. To help meet the immediate requirement for in-service teacher training, colleges of education will usually need to enlist the assistance of computer science departments or computer centers in their respective institutions. Training in the use of computer technology must include opportunities to observe and participate in a variety of situations where computers are used. Sufficient computer facilities must be available for actual use by prospective teachers. It is also important to convey to the teacher that the computer can assist him but will not displace him.

We therefore recommend that the National Science Foundation sponsor the development of a basic curriculum to train high school teachers in the use of computers in all disciplines. In addition, a curriculum should be developed to train those teachers *who will be requested to teach the more in-depth courses involving computing.*

The basic curriculum in computer use should *not* be restricted to just the mathematics teachers but should be for teachers of all subjects, with special attention to computer applications in those subjects, and should prepare teachers to teach the computer literacy course for students. The actual course materials for both curricula should be so prepared that though the emphasis would be on pre-service education they could also be used for in-service training.

These course materials should form the basis for curricula in NSF supported summer institutes to train the “teacher trainers”. *It is recommended that NSF also sponsor the development of outlines of curricula for these institutes*. These outlines, which could also be used by traveling lecturers as the basis for a two-week intensive course, should call for a clear, well-documented package, to be developed and taught by a select group of people specially qualified for the task.

That educators in one school need to know what those in other schools are doing is of course a truism. Unfortunately, such communication is not very effective at present, and means will need to be developed for more efficient communications among such groups, through conferences, publications, and other means. This problem is discussed in detail in the next Section.

9. Dissemination of Information

As noted in the preface to the present report, considerable activity has been taking place in various parts of the country in the area of computer assisted instruction (CAI), broadly interpreted to include not only drill and practice, or interactive learning with the computer, but also simulation and problem solving activities as well. Examples of these efforts can be found in such compilations and reviews as [9], [18], [19], [20]. In addition, reports such as [5] received by this Committee, as well as site visits made under the sponsorship of the Committee, indicate that computing is fast becoming an integral part of public education. At the present time, the greatest use of computing facilities in education is in large population centers; but as computing equipment costs decrease, it can be anticipated that many more schools and colleges will soon have access to some type of computing facility for instructional purposes.

Unfortunately, dissemination of information and curriculum materials has not kept pace with the rapid growth of these computing activities. This has already resulted in considerable duplication of effort. While it is often desirable to have different approaches to computer uses in a specific curriculum area (e.g., more than one drill and practice model for developing skill in computation or textual material for the application of the computer in algebra), curriculum development groups could proceed more effectively if they were in position to consider first what has already been done. Without such precaution, duplication may even result in poorer quality products, since in many cases the models already available are the excellent result of major commitment of funds and skilled personnel.

For example, in CAI tutorial drill and practice, the Stanford Project and the Honeywell Arithmetic Test Generation (ATG) system each reflect such major efforts. A number of significant efforts have been made in developing curriculum materials in the area of computer programming as a problem solving tool in school science and mathematics (see, e.g., [1], [2], [12] -[17]). Simulation activities, while more recent, have also been developed by a number of projects or school systems. Examples include the Huntington II Computer Project at the Polytechnic Institute of Brooklyn, the TIES (Total Information for Educational Systems) project of the Minnesota School Districts Data Processing Joint Board at Saint Paul, and projects of the Instructional Computing Center of the School District of Philadelphia.

The above activities represent only a small portion of the curriculum developments taking place. Many individual schools and school systems are, and have been, preparing materials. In most cases, however, little exchange of information is taking place among schools. When exchange does occur, it usually is the result of personal contact or is due to the availability of someone knowledgeable about activities going on in other parts of the country. It is true that NSF computing conferences and sections at annual meetings of professional organizations have provided for some exchange of general information and some visibility to ongoing projects; and there should be more such conferences and meetings.

The need for easy access to detailed information about materials is critical. While it is true that the concerned consumer can contact the project centers for information (if he knows about them), often the information itself is sketchy or in the case of "computerized learning" and simulation, the documentation may be inadequate or incompatible with equipment other than the system for which the material was originally developed. In addition to the problem of proper documentation, much of the material now "available" is still in early stages of development and has had little or no testing and evaluation. (The exceptions to this are primarily in the areas of drill and practice activities, where for some reason people continue to test materials which have been demonstrated to work many times over. This again might be attributed to the fact that the consumer is not knowledgeable about the research already completed.)

We recommend that there be established a National Center for Computing Activities in the Schools to serve as a clearinghouse for information.

The services provided by this Center should have the following features.

a. Both general and detailed *computerized*, bibliographical information should be available to schools. The information should be classified with descriptors similar to those used currently in the ERIC Centers. The listing should include not only information on project developed materials but also materials developed commercially or by individuals. For example, the Center could start with the bibliographies indicated at the outset of this Section. Wide visibility must be an early goal for the Center, which should encourage the submitting of materials of even a very specific nature, e. g., individual simulations for a radioactive growth and decay setting, or installment purchasing.

b. Frequent listings within curricular areas, (content area and/or type of computing activity) should be distributed by the Center to professional journals for publication. (e. g., for science and mathematics these journals would include the *Mathematics Teacher*, the *Arithmetic Teacher*, the *American Mathematical Monthly*, *ACM Communications*, and *School Science and Mathematics*.)

c. The Center should be staffed in such a way as to be able either to prepare the documentation necessary to make materials compatible with a wide range of facilities or to suggest a source for such a service. This service is particularly relevant for simulation and other Cal interactive learning activities. Hence there will be a need for access to a broad base of subject matter specialists as well as computer programmers or systems personnel. The Center might well recommend the standardization of language needed to achieve compatibility.

d. In the case of many duplications of a particular application, the Center should have complete documentation of at least one of these, with brief "abstract" data on the others. This will necessitate regular review and evaluation (as well as updating for improvements).

e. The Center should have a tie to designated "testing centers", which will provide research and evaluation services. That is, a secondary level or supporting unit of the Center should be staffed and organized to *provide* testing and evaluation and recommend modifications in the materials submitted. (While this is not a specified Center activity, the Center might provide the administrative function for this unit.)

While many of the above functions might well be incorporated into the existing Stanford ERIC Center, the above items call for services which go beyond those currently provided. In addition, the Center should consider further classifying the computer materials in terms of subject area, grade level and type of computer activity: (1) computer assisted learning (actual presentation of learning materials and interaction), (2) simulations, and (3) computer programming as a problem solving tool. For materials not commercially available the Center should be set up to provide the complete instructional "packages" at a nominal fee. In the case of commercial materials, selected samples of the materials should be in the system, again calling for regular updating and modification.

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