DOCUMENT RESUME

ED 223 445 SE 039 611

TITLE	A Report on the Four NSF-NIE Regional Conferences on Improving Mathematics Education through the Use of Information Technology.
INSTITUTION	National Inst. of Education (ED), Washington, DC.; National Science Foundation, Washington, D.C.
PUB DATE	81
NOTE	74p.
PUB TYPE	Collected Works - Conference Proceedings (021)
EDRS PRICE	MF01/PC03 Plus Postage.
DESCRIPTORS	Computers; Computer Science; Computer Science Education; Conferences; Curriculum Development; Educational Change; *Educational Technology; Elementary Secondary Education; *Mathematics Curriculum; *Mathematics Education; *Mathematics Instruction; *Microcomputers
IDENTIFIERS	*National Institute of Education; *National Science Foundation

ABSTRACT

The material presents: (1) an overview of the Regional Conferences (2) a paper on Mathematics, Microelectronics, and American Education (F. James Rutherford and Joseph M. Dasbach), and (3) individual presentations on the Regional Meetings in Berkeley, Chicago, Newton, Massachusetts, and Washington, D.C. The meetings were designed to encourage communication between grantees and persons with an interest in computer use in education. The meetings typically lasted 1.5 days, and consisted of a mixture of presentations by participants and discussion. At a final wrap-up session in Washington, D.C., six interrelated issues were discussed which were viewed to have arisen consistently in the regional meetings. These were: (1) the need for a "new look" at the mathematics curriculum; (2) the need for software and hardware of high quality; (3) the need for support structures that will allow teachers at all levels to use computer technology in their classrooms; (4) the education of educators; and (5) the need for wide dissemination of information about computers and how they can be used in mathematics instruction. The document concludes with lists of the regional meeting participants. (MP)

A REPORT ON THE FOUR NSF-NIE REGIONAL CONFERENCES ON IMPROVING MATHEMATICS EDUCATION THROUGH THE USE OF INFORMATION TECHNOLOGY

Summer, 1981

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The National Institute of Education
U.S. Department of Health, Education and Welfare
Washington, D.C. 20208

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ACKNOWLEDGMENTS

We express appreciation to the staff of Courtesy Associates for their work in coordinating and arranging for the meetings. Specifically, we thank Doris Vermilya, Gretchen Moore and especially Andrea Semmes, who carried the major responsibility for Courtesy Associates.

We also express our thanks to those responsible for making the arrangements for the meetings at each site: in Berkeley, Arthur Kessner and Barbara Ando; in Chicago, Dorothy Strong, William B. Duffie, Rita Cooney, Yolanda Crane and Joyce Price; in Newton, Ross Finney, Felicia M. DeMay, Sol Garfunkel and Camilla Madson. The Washington meeting was arranged by staff members of the National Institute of Education and the National Science Foundation, with some technical assistance from Keith Johnson.

Finally, we thank the participants who gave generously of their time, expertise and creative talents to make the meetings successful.

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AN OVERVIEW OF THE NSF-NIE REGIONAL CONFERENCES

Edward Esty
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History of the NSF-NIE Program

1980 the National Science Foundation and the National Institute of Education initiated a joint program concerned with mathematics education and computer technology. The first phase of the program was designed to encourage the development of prototypes of educationally relevant software, instructional courseware, and methods for assessing students' progress. The program announcement stated that "The objective of the first year's competition is to support projects...for development of a variety of innovative and imaginative approaches to mathematics instruction using information technology... Projects designed to produce, during their first year, working models...that clearly illustrate the new approach are particularly appropriate."

By the first deadline in February, 1980, we had received about 180 proposals, of which the joint program eventually funded nine. The National Science Foundation supported additional projects that stemmed from the grants announcement with funds from their programs in Development in Science Education and Research in Science Education. The second deadline (August, 1980) produced 116 proposals, of which the joint program supported six; again NSF funded some additional projects. Information about all of these projects, including abstracts, dates, and amounts of awards, is contained in a publication entitled "Pre-College Mathematics Education Using Computes" (SE 82-51), which is available from NSF.

Related to the joint program, although not a part of it, was a contract that NIE awarded to the Bank Street College of Education. In that project Karen Shiengold studied three school districts intensively in an attempt to discern what factors affect the successful implementation of computer technology. Dr. Shiengold's final report, "Study of Issues Related to Implementation of Computer Technology in Schools," is available through the ERIC system.

Later, NIE issued a Request for Proposals for a research project that would determine the kinds and levels of knowledge that teachers need in order to use computer technology effectively in their classrooms. It is anticipated that an award in that competition will be made by the end of March, 1982.

The Regional Conferences

In an effort to encourage communication among our grantees and other persons with an interest in or concern with computer use in education, the NSF-NIE program then sponsored a series of meetings in the summer of 1981, of which this volume is a report. To minimize travel costs, we first determined which major metropolitan areas were closest to the majority of our grantees. This resulted in the selection of Berkeley, Chicago, Newton (Massachusetts) and Washington, DC as the sites. The way the grantees were spread geographically led us to a plan whereby each meeting would have about 20 participants, approximately ten of whom would be grantees. The other participants were chosen so that we could get input from several different groups: teachers, school administrators and supervisors, publishers, software and hardware vendors, and psychologists concerned with learning in and out of schools. The distribution of the grantees and other participants among the four conferences resulted in each meeting's having a particular theme or emphasis, as indicated in the chart below:

Place	Dates	Theme
Berkeley, CA	June 14-16, 1981	Mathematics learning via microcomputers in formal and informal settings
Chicago, IL	June 28-30, 1981	The role of publishers in improving mathematics education through information technology
Newton, MA	July 7-9, 1981	The role of teachers in using microcomputers in mathematics education
Washington, DC	July 15-17, 1981	The role of governments in mathematics education and information technology

Despite the existence of these "themes", it should be emphasized that no one at any of the meetings felt contrained limit his or her thinking to the "official" topics; indeed, the discussions at all the sites covered a very broad range of issues.

Ordinarily, the meetings were one-and-one-half days in length, with an introductory evening session at the beginning. (The Washington meeting was somewhat longer.) The format consisted of a mixture of demonstrations by NSF-NIE grantees (and other participants) and discussion. Some of the work was done in smaller groups, which then reported back to a final plenary session. Detailed descriptions of the proceedings of each meeting can be found in Chapters 3 through 6.

Papers from the Meetings

Three different kinds of documents resulted from the conferences:

1. First, the participants were asked to prepare papers of about three pages in length before the meetings began. These were to be on any aspect of the relationship between mathematics and information technology that the participants felt to be important. In particular, we accompanied each invitation with a copy of the National Council of Teachers of Mathematics' An Agenda for Action, and suggested that the invitees might want to comment on some fact of the recommendations presented in that NCTM booklet. These papers will be compiled into a separate volume, which will be available through the ERIC system.

2. Second, we asked one person at each of the meetings to act as a summarizer of that particular meeting. Diane Resek, Lynn Steen, Edith Luchins and Joyce Hakanssen graciously agreed to take on that added responsibility at the Berkeley, Chicago, Newton and Washingtion meetings, respectively. Each has prepared a paper that describes what happened at the meeting and summarizes the major points of discussion, agreement, or disagreement. Their four paper, one for each conference are contained in this book as Chapters 3 through 6.

3. Finally, we asked F. James Rutherford and Joseph Dasbach to attend all four of the meetings and to prepare a paper setting forth the major issues related to mathematics and information technology as they saw them. Their paper, to which I have added some marginal notes connecting their discussion to points raised in individual participants' papers and in the regional summary papers, appears as the next chapter of this volume.

Emerging Issues

Following the last of the four regional meetings, a final wrap-up session was held in Washington. The four summarizers, Drs. Rutherford and Dasbach, and staff from the National Science Foundation and NIE attended. The purpose was to look back over the preceding sessions and to identify any issues that had arisen so consistently that they should be highlighted in the final report. Six such issues, all of which are interrelated, emerged:

1. The need for a "new look" at the mathematics curriculum came up repeatedly at all four of the meetings. Clearly there is a two-way interaction between computers and the curriculum: One the one hand, adults' mathematical needs in the coming years will be profoundly affected by the existence of computers, and on the other hand, computer technology will make possible far more effective ways of teaching mathematics.

2. The need for software and hardware of high quality was stressed throughout the meetings. The computer equipment itself (hardware) must be reliable and sturdy enough to withstand classroom use, and the instructional programs (software) must be soundly designed. Even now there are good examples of instructional software, but the quantity of excellent software must be vastly increased if the potential of computing in schools is to be realized.

3. The is a need for support structures that will allow teachers at all levels to use computer technology in their classrooms. Even if software and hardware of sufficient quality and quantity are available, teachers will still need assistance of various kinds to use the materials effectively.

4. The education of educators is a necessary ingredient. Educators in all kinds of positions--particularly including administrators and members of school boards--must be informed about the promising uses of computers in mathematics education so that they can make wise decisions within their own local communities.

5. The involvement of all citizens is essential to the overall success of computers in mathematics education. A knowledge of mathematics and computing is today a key to advancement in many careers. We must be sure that that knowledge is accessible to all of our citizens, especially those from groups that traditionally been underrepresented in technological fields.

6. Finally, there is a need for wide dissemination of information about computers and how they can be used in mathematics instruction. We must share that information particularly with parents. Only by virtue of a strong base of public understanding of the issues involved can we expect to make a lasting impact on mathematics education.

All of these issues, and many others as well, were topics of debate and disscussion at the regional meetings. The chapters that follow examine them in much greater detail.

MATHEMATICS, MICROELECTRONICS, AND AMERICAN EDUCATION

F. James Rutherford and Joseph M. Dasbach
American Association for the Advancement of Science

INTRODUCTION

How will the "microcomputer revolution" affect mathematics learning, if at all? Are we on the verge, as some predict, of a radical change in what mathematics is to be learned, how it is taught, and where it is learned? Or are we once again seeing a promising technology pass education by with scarcely a trace, even though the technology (microcomputers) and the content (mathematics) are first cousins? Or, as history might suggest, isn't it likely that the result will be mixed but skewed, with most of the educational benefits going to a select few in our more prosperous schools and homes?

For those of us interested in influencing the future, and who intend to be active participants in whatever occurs rather than merely observers of it, an examination of microcomputers in mathematics education needs to start realistically and positively. Instead of speculating on whether microcomputers will provoke a revolution in mathematics teaching, we ask: What needs to be done now to ensure that microcomputer technology is wisely exploited to improve the quality of mathematics education in America and increase its accessibility to all our citizens? How can we use microcomputers to help develop a mathematically literate Nation?

Certain presuppositions are implicit in the essay that follows on how mathematics education can best take advantage of the revolution in microcomputers. Briefly, these assumptions include the points that follow.

- The "microcomputer revolution" is not just a routine technical advance but a dramatic, radical technological change occurring right now with profound societal implications. Thanks to the development of effective processes for manufacturing microelectronic "chips," microcomputers are radically reduced in size and cost from their ancestors. They fit atop desks, and do nearly everything that used to take room-sized computers to do.

  In terms of societal impact, the microcomputer revolution may ultimately come to be as significant as the industrial revolution. The microcomputer is in the process of changing the way we do our work, run our households, operate our machines, and, perhaps, the way we do our thinking. The device is appearing virtually everywhere. Alone and in combination with videodiscs, sensors, typewriters, printers, robots, and even with other computers, the microcomputer is showing up in the factory, the office, the university, the laboratory, the home, the marketplace, the library, the bar, the arcade, and even in some schools.

- There is an urgent national need to better the mathematics education of all students. Careers and civic responsibilities today already demand more mathematical knowledge and quantitative reasoning skills than ever before in history. As our dependence on technology continues to grow rapidly, so too will the mathematical demands it places on students heading toward technology-based careers, and on all future citizens, though in a different way. Yet fewer Americans than ever are required to study mathematics at all beyond elementary algebra, or elect to do so. And the quality of what little mathematics we do teach appears to be in decline. Science education, another first cousin of mathematics, is in a similar state across the country.

These problems are not the problems of Arizona, or Seattle, or the Northeast; they are problems of our Nation. In stark contrast to the lassitude within the United States, our foreign allies and adversaries--both economic and military--are bolstering the amount and sophistication of precollege mathematics required of all students.

- Microcomputers can be powerful aids in helping people learn a variety of mathematics from simple arithmetic through complex mathematical reasoning and problem-solving. However, incorporating microcomputers into American mathematics education involves considerably more than just the intrinsic capability of the electronic machine and the ingenuity (and mathematical knowledge) of the persons who develop its programs. It also hinges on a number of thorny issues of interest to teachers and administrators, publishers, parents, and the general public.

- It is time for action, since microcomputers are here and proliferating. We should begin without delay the systematic and thoughtful introduction of microcomputers into the schools as a standard tool of mathematics learning at all educational levels. In doing this, we must ask what activities in mathematics will the microcomputers be used for, to what end, on what scale, by whom, and at whose cost. Research and development on both computer technology and mathematics learning need to continue, and indeed should be greatly accelerated, for they are indispensable to long-term progress.

- The wise exploitation of microcomputers for the sake of better mathematics learning is our primary interest, not the machines for their own sake, however fascinating they may be. To ensure progress, we must deal thoughtfully with goals, people, traditions, and circumstances; and we must be imaginative yet practical in proposing action in the face of the diversity, discontinuities, and fragmentation that characterize American education in our 50 States.

Clearly, "microcomputers in mathematics education" is not a topic that can be usefully examined in isolation from concern for the fundamental values of American society and purposes of American education. General beliefs about and attitudes toward modern science, technology, and education color, and rightfully so, any consideration of the educational use of this impressive new technology.

The following sections deal in order with educational perspectives, the potential uses of microcomputers in mathematics learning, what circumstances need to be dealt with in order to realize the microcomputer's potential, and, finally, some strategic considerations and possibilities for action.

PERSPECTIVES ON TECHNOLOGICAL INNOVATION IN AMERICAN EDUCATION

For microcomputer technology to stimulate major changes in mathematics learning on a national scale, it must do so in the context of the prevailing circumstances, beliefs, and attitudes in which American education finds itself today. Particular educational issues of national consequence, such as the use of microcomputers in mathematics education, are not likely to make much sense unless viewed from a larger educational perspective. Yet that larger view is difficult to sketch simply. The American educational system is not really a system at all, but a large collection of independent institutions, businesses, and authorities engaged in a myriad of educational and administrative activities. Almost any general statement one makes about education in the United States--about its teachers, schools and colleges, students, policies, budgets, publishers, or whatever--is bound to be both true and false, depending upon time and place. Statements of a general nature about the national educational enterprise usually have as many exceptions as exemplars.

Nevertheless, we offer the following generalizations in the belief that they reflect the state of education in the United States accurately enough to provide some useful perspectives.

1. *Americans believe that public education is currently bad and getting worse.* It has long been an article of faith among Americans that education is the road to personal and collective advancement. Because of its perceived importance, education nationally has been compulsory and universal, even though educational systems operate under State and local authorities.

In recent decades, the educational preoccupation of America has been with the equitable access to education of all youngsters regardless of class, race, or sex. This national concern was responsible for the intervention of the Federal Government and of the courts into educational matters at State and local levels. Except during the few years immediately following the launch of Sputnik, the concern and the public debate had to do with questions of access and opportunity, rarely with the quality of the education being offered to our youth.

In the early 1970's that concern began to change. More and more the popular press featured news and articles depicting deterioration of the public schools. American students were graduating barely able to read, write, and do ordinary calculations. They were pictured as taking the easy courses in high school and avoiding science, mathematics, foreign languages, and other traditional academic fare. In addition, there were charges that schools were out of control, that the buildings and grounds were not safe, and that drug use was increasing in high schools and even junior high schools.

Some of these reports were factual. Most notable were the test score declines. Average achievement test scores of the U.S. students on all widely administered tests, such as the Scholastic Aptitude Test, the American College Testing Program, and the Iowa Test of Educational Development, showed a steady and continuing decline from the early 1960's to the present time. This was reinforced by scores on the National Assessment of Educational Progress, begun in 1970, that showed declines in many areas of learning. Also, evidence began to accumulate that enrollment patterns were changing. For example, enrollments in science and mathematics shrank noticeably in the 1970's. School behavior problems were more difficult to document, but newspapers and television reportters had no difficulty in keeping instances of violence and drug use in the public eye. Successes in the schools, perhaps less newsworthy, rarely reached the general public.

Because the issues surrounding the conditions of the public schools are complex, the public outcry, although justified, is perhaps exaggerated. Nevertheless, the "back to basics" movement was launched with solid public backing. The movement, along with the severe financial and staff cutbacks experienced in many schools and the persistent and often shrill public deprecation of teachers and educators, may in fact have led to a further worsening of the quality of education.

In spite of successes that are quite impressive when viewed in the perspective of the entire 20th century, as we enter the 1980's American schools clearly are not operating up to the public's expectations; confidence in the system of public education continues to wane.

2. *The American educational system is experiencing enormous stresses and strains.* A loss of confidence in public education need not have been the public response to the real and perceived weaknesses of our country's educational system. Throughout its history, American public education has had its ups and downs. In the past, however, the public's response to decline has frequently been to join together to <u>improve</u> education in America. For example, after the shock of Sputnik there was a substantial effort, publicly supported, to upgrade scientific, mathematics, and foreign language education across the Nation, including the upgrading of teachers. Today, economic shocks overshadow our academic problems, and the public response seems to be a retreat from participation in public education, and either to blame teachers harshly for the schools' failures or to pity them for having to work in them. The fall of public school teachers from community esteem is particularly vexing because it begs explanation and because it may be a key element in the decision of parents to withdraw their children from public schools. Some of the factors that currently contribute to the severe strain felt in the public schools are mentioned here.

- The media continue to question the competency of teachers and the quality of public education, presenting the schools in a generally negative light and emphasizing their failures. What few successes are reported are almost always in nonpublic institutions or in the wealthier suburban public school districts. Educators who have come to believe that they have lost community respect, perhaps even feeling besieged, may not be in a mood to experiment with new methods. Hunkering down, embracing "back to the basics" in its simplest form, increasing reliance on textbooks, and concentrating on improving test scores may seem to be the safest way to respond to the relentless media criticism.

- Major but not well understood changes are taking place in the financial structure of support for public education. With most local tax bases shrinking, State investment and control have grown. The Federal Government has begun reducing its support for public education even while searching for Federal ways to encourage nonpublic elementary and secondary education. The end results of these changes are yet unclear, but they are likely to affect different schools in different ways, thereby exacerbating tensions among them. For example, some school districts are far more dependent than others on impact aid and other Federal programs, and consequently stand to be hurt more by cutbacks.

- Throughout the last two decades population dips and shifts have changed the makeup of classrooms. Emerging issues such as school closings, bilingual education, mainstreaming, busing, and student promotion practices have engulfed the schools in acrimonious political storms. These are both local and national in scope, they never seem to let up, and they push and pull in different directions.

- Just at the time when school populations have stopped expanding, financial squeezes have brought large layoffs of teachers and support personnel. Furthermore, since reductions have generally been made on the basis of seniority, and since new teachers are not being hired in any numbers, the distribution of teachers in public schools is increasingly skewed toward higher age and longer service. Teachers in certain fields such as mathematics are being recruited by business and industry as computer programers and analysts, making it necessary for some schools to resort to the use of underqualified mathematics teachers.

- The balance of power between teachers and administrators, teachers and students, and educators and the local community has been in flux for at least two decades, and it continues to shift. Changing demands, expectations, and priorities keep the system off balance and the local participants (teachers, administrators, students, parents, and community authorities) at odds with each other much of the time. The resulting tensions are in addition to those caused by the competing claims of authority among the local schools and the various regional, State, and Federal agencies and courts.

How might these stresses and strains affect the possibility for innovation in mathematics learning? It could be argued that the schools are currently too distracted by existing problems to be able to cope with innovation, for introducing new curriculums or methods or technologies is of itself a stressful enterprise. But perhaps the reverse is true. Given current public attitudes toward the schools, and the educators' struggles with current finances and with special interest groups, the stage may be set for the acceptance of substantial, if not radical, innovations.

3. *Innovation in American schools is a hit-or-miss affair.* Viewed historically and internationally, no country has a more impressive record of educational invention than the United States. Other countries routinely use American ideas to update their curriculums. America is a treasure house of ideas; yet from a national perspective and over shorter time spans, our record as innovators is very much less impressive than most Americans believe. Given our commitment to education and our fascination with novelty, we might expect reform to be a continuous and abiding characteristic of American education. In fact, rarely has there been a sustained national commitment to innovation in elementary and secondary education the way there has been, for instance, to innovation in communications, transportation, health, and agriculture. Perhaps this is because other fields do not face the formidable competition for time and the major distractions that confront education. In a word, they don't have to cope and compete with TV. In any case, there is a dramatic contrast between the

especially rapid and accelerating rate of change in microelectronics and the slow pace of change in public education.

In considering the process of change, we first note that the fragmentation of the American school system makes small-scale experimentation easier. Individual teachers, schools, school districts, and States can undertake innovations that would be difficult to initiate in nationally centralized systems. Bureaucratic resistance to change is more dispersed and less an obstacle in our system of shared powers than elsewhere in the world. But the same fragmentation that enables experimentation locally inhibits widespread or uniform change on a national scale. Thus, a promising innovation in mathematics at a few schools in one or two States has difficulty spreading to other locales. One of the ironies of this is that, instead of promoting diversity, fragmentation permits a homogenization of textbooks and curriculums to occur by giving extraordinary power to commercial textbook publishers and certain textbook "adoption States."

Often our experimentation and efforts at innovation are piecemeal and disconnected. We usually focus our attention narrowly: on this or that particular subject in isolation rather than in relation to the entire school curriculum; on one grade level as though it were independent of the entire spectrum of grades; on individual subjects and courses instead of on concepts and skills that cut across courses and grade levels; on curriculum change or methodological change or technological change, but not on all three at once.

One stultifying result of our fragmented system is the difficulty it presents us in establishing our educational goals as a Nation. The Federal Government does not prescribe national goals, but reaching a consensus as a Nation is difficult because the schools and educators are too numerous and too dispersed geographically to work together. Without even broad national goals to energize and direct the enterprise, the path of educational progress is more likely to resemble the drunkard's walk than a spacecraft's smooth and targeted trajectory. This situation emphasizes that there is no mechanism for instituting needed national change without a Federal role.

Since there is no stable provision for educational innovation in State or Federal budgets, it is extremely difficult to get financial support for major innovations that may take millions of dollars and many years to develop, test, and incorporate. To attract the necessary funding, it is tempting to resort to hyperbole. The science and mathematics curriculum developers of the 1960's may have overstated their proposed innovations in order to gain support they needed. Exaggerated promises of quick and dramatic results raise public expectations to such a high level that they become unrealizable, often leading to a common judgment of failure, and thereby impeding an innovation's adoption on a national scale. Such "failure" also makes garnering support for the next stage of innovation even more difficult, which aggravates still further the tendency to inflate the claims for the proposed innovation.

4. *Education today remains technologically underdeveloped.* The first question Americans ask about a new product of technology is: How can it be used to turn a profit? It is rare that we initially ask, How can this new product be developed and designed so as to improve American education? Thus, radio, the first of the electronic technologies with enormous potential for education, was immediately put to work in the United States selling merchandise. Because its sole purpose was profit, it naturally turned to the kind of broadcasts--

popular entertainment--that would attract the largest possible audiences. Over the decades very little corporate investment was made in educational radio. It remains one of the most powerful and educationally unexploited technologies around.

Television essentially has repeated the history of radio, although TV use in classrooms and as a home educational instrument has been somewhat better than radio. Still, in TV, selling and profitmaking are primary. Slides, motion pictures, and other optical media are widely used in schools, but the educational uses had to be fashioned out of equipment originally designed for entertainment purposes. The videocassette seems well on the way to another such rerun.

The American pattern is clear. The educational exploitation of technologies is always secondary to the prevalent market orientation and philosophy. Educational technologies always follow commercial development, almost as an afterthought. And they must survive on a tiny research and development expenditure at best. Technology for education simply is not viewed as a long-term investment in the economy of the Nation. Late starts and insufficient research and development investment can guarantee only timid and often unimaginative use of the technologies. Consider the following.

- School curriculums and individual courses are rarely reexamined in toto in the light of new curriculum possibilities afforded by technologies. Support for the status quo, rather than curriculum reform, is the usual application.

- Schools typically fail to set up support systems to ensure the effective use of technologies. In businesses and industry, it is understood that machine users need vital help from time to time, and that machines do not run forever, but need systematic attention. Although some school systems operate media centers, even television stations, these are frequently remote and bureaucratically inhibiting, leaving the teacher without much technical staff support in the classroom itself.

- New products of technology are made available but teachers receive little or no systematic training in their use, either as part of their preservice preparation or in their continuing education. For example, very few schools of education have yet changed their requirements to ensure that every graduating teacher is competent in the use of microcomputers.

- The textbook is the most widely used technology in education today, be it for mathematics, science, history, or driver education. Teachers and publishers, and perhaps the public, find it difficult to think of any other technology as being more than a supplemental aid, or even a frill. Thus, it is rare that motion pictures or any other technology are integrated into the substance of a course. They continue to remain peripheral.

OPPORTUNITIES FOR THE USE OF MICROCOMPUTERS IN MATHEMATICS EDUCATION

Microcomputers offer a rich potential for the betterment of mathematics learning. Some of the short papers that were prepared by the participants at the NSF-NIE regional meetings give ample testimony to what teachers and developers across the country can do under favorable circumstances. This is not to say that microcomputers will be so used on a significant scale nationally, but only that the possibilities are many and real and exciting.

What opportunities beckon? A few of the possibilities are presented here according to different purposes to be served with microcomputers.

1. *To enrich mathematics instruction in the classroom.* Unlike promising new technologies of the past, the microcomputer can be directed to perform computations, can "remember," can be used as part of a laboratory instrument (e.g., measuring temperature of a solution with an attached thermistor), can plot graphs (and modify, superimpose, or juxtapose them), and can interact with a human being based on his or her responses. The microcomputer is number-oriented and data-oriented. Data from the real world can be incorporated into classroom mathematics. For example, there is a wealth of numerical data available from sciences and engineering, weather, sports, business and commerce, and the census--national, State, and local. The University of Michigan alone maintains some 300 special data bases. Meaningful numbers in the daily newspaper, monthly magazines, and journals can be only a keyboard away. In addition, teachers and students can easily build their own data banks over time related to the local school and community environment.

The microcomputer offers many other opportunities for the betterment of mathematics teaching because of its ability to connect with other information and communications technologies. One of the most promising combinations near at hand is the so-called "intelligent" videodisc--the microcomputer linked to the videodisc. The interactive power of the microcomputer having direct and rapid access to the vast visual and auditory storage capacity of the videodisc means that teachers and students can have available a rich audiovisual library of slides, films, and graphics related to the mathematics being studied. While these could all in principle be available physically or on a plain videodisc, technical, logistical, and economic realities rarely enable access to the teacher or student at the time when it is psychologically most needed. The

At the Berkeley meeting, Judd demonstrated an example of how this could work. Similarly, Long showed the power of a videodisc system at the Washington meeting. Also see the papers of Landesman & Karwin and Judd.

Other possibilities appear in Luchins' paper and in Rowan's paper.

microcomputer gives immediate access to just what is needed, when it is needed, as often as needed.

2. *To introduce new pedagogical techniques.* As in most professions, progress in education depends in principle on the introduction of new techniques in its practice. New products of technology often stimulate new techniques. Today microcomputers probably offer the greatest opportunity in modern times for changing dramatically the ways in which mathematics is taught. Consider just a few of the many new approaches now being developed by teachers, mathematicians, and computer scientists.

At the Washington meeting, Davis described how microcomputers are used to process data from scientific experiments. Also see Saltinski's paper on statistics.

- The application of mathematical analysis to problems using real-world data. This not only offers a sense of immediacy and relevancy to student work in mathematics but also gives experience doing mathematics the way it will be done by most adults in the future, that is, by using mathematical and microelectronic tools to deal with real data.

The four meetings were replete with examples of games and simulations. Among the many demonstrations were those of Kraus (Boston), Dugdale (Chicago and Washington), and Perl (Berkeley). Also see the papers of Laurel, Manzelli, and Staib.

- The use of meaningful computer games and simulations that involve students in logic, hypothetical thinking, inventing mathematical concepts, and shifting their frames of reference. The idea is to promote the kind of mathematical thinking that goes beyond simple computation, and to do so in captivating ways.

Other examples: materials written by Resek and Finzer described at Berkeley; demonstrations of LOGO environments at the Boston meeting; Seidel's demonstrations at the Washington meeting.

- The design of classroom computer environments in which students can at times personally develop mathematical concepts based on their own experiences rather than solely on authority. An example of this is "turtle geometry," in which students learn first to control the motion of a small robot, then to program its motion with "mathematical commands" through the computer, and finally to work with a dot moving on a screen instead of the mechanical turtle as they progressively use the computer to develop geometric concepts.

An excellent example of this is the work of Hakes, which she demonstrated at the Berkeley meeting. See also Kee's paper.

- The use of cooperative small group learning in place of almost exclusive reliance on competitive individual learning. Again this matches reality. In most enterprises, teamwork and cooperation--or at least group action in solving real-world problems, including those that require application of mathematical thinking--are the common practice. The microcomputer permits, almost demands, cooperative approaches to problem-solving in the classroom and out. Should we not encourage and enable students to experience more cooperation in their learning? If students cooperate in their learning, will they not also learn cooperation?

One example of this was described by Swadener at the Berkeley meeting.

- One of the natural consequences of a microcomputer group approach to mathematical problem-solving is that students teach each other. Those students who are more adroit with technological devices help others in the group become competent, those who are more analytical show the others how to approach a problem, those who have better graphic skills guide the others, and so on. The introduction of microcomputers even makes possible and sensible the increased use of students as informal instructors across grades. Some students in high school and even as early as the sixth or seventh grade quickly develop incredible computer skills, and many of them make effective instructors of younger children and even adults. Needless to say, such a pedagogical shift would require a reordering of the traditional mathematics classrooms.

3. *To individualize access to mathematics learning.* The microcomputer is unlike any previous educational technology in that it permits the design of substantial amounts of instruction for individuals who have vastly different knowledge, skills, and predispositions. It can address personal idiosyncrasies in learning, which is to say that the microcomputer can be designed to serve as a skillful tutor of mathematics.

Another approach is to use the microcomputer as a guide rather than as an instructor. Using dialog routines and sophisticated concept and skill testing, the microcomputer can help the teacher and student decide which topics to study next, precisely where to find good instruction on that topic, and how well the student understands it at any time. This kind of guidance should be especially effective in teaching problem-solving skills because of its capacity to test those skills in a variety of substantive contexts and to any level of difficulty desired by the teacher or student.

4. *To reach special populations.* When it comes to the allocation of teaching resources--good teachers, facilities, up-to-date textbooks, well-stocked libraries, and new technologies--some Americans have historically been better served than others. It may not be national policy but that is clearly how it has worked out. In what is surely the great challenge in contemporary education the world around, part of our failure has been restraint. We have held back from the imaginative and widespread use of new technologies, such as radio and television, explicitly to help bring educationally underserved populations up to parity. Children's Television Workshop productions such as Sesame Street and 3-2-1 Contact contribute no more than a tiny portion of the TV menu for such children.

Now we have another chance. It is perhaps our best opportunity to date, given the interactive nature of the newest technology and the possibility of using it in conjunction with other technologies, new and old. Microcomputers now make it entirely feasible to overcome many of the obstacles to a good mathematics education faced by such Americans as:

Other special populations were discussed by Kee at the Berkeley meeting.

- children of migrant workers,
- inner-city school dropouts (or turned-off stay-ins),
- children and adults who do not yet understand English,
- persons who are institutionalized or otherwise immobilized,
- children in the growing number of schools suffering a severe shortage of competent mathematics teachers,
- girls, young women, and women, and
- minorities.

The population of females was the focus of a considerable amount of discussion at the Berkeley meeting, in part stemming from Laurel's presentation. See also the summary of the Chicago meeting.

If we practice restraint again and do nothing, this same microcomputer technology will most likely increase the gap separating these Americans from the mainstream. We will have ignored important human resources--mind power as well as body power--vital to a strong America in upcoming decades. Because of the importance of mathematics to living in the modern world we cannot afford to deny any of our American youth an adequate education in mathematics. And there is more to be gained by exploiting microcomputers on behalf of the underserved than just providing them a sound mathematics education, as critically important as that is. It can help these same Americans leapfrog into our computer-oriented future. Knowing how to use computers, being able to deal effectively and confidently with numbers and quantities, and doing problem-solving with the aid of computers will more and more be a demand of the job market. This is rapidly becoming true in all fields of endeavor and at all levels of employment.

Compare this with Resek's paper on lowering the algebra barrier.

5. *To instigate curriculum renewal in mathematics.* It is true that microcomputers can be restricted to preserving the status quo by simply enriching the existing mathematics curriculum and teaching it more efficiently. But why not acknowledge that full educational exploitation of the power of the microcomputer demands that the mathematics curriculum be reexamined almost from beginning to end? The art of programing computers is progressing to the point that requires our asking about what content is to be taught, at what levels, in which contexts, to what achievement levels, for what purposes. The conclusion reached from such an examination might possibly be to keep everything the way it is. However, once the curriculum is opened up for critical inspection, more future-oriented answers may emerge.

This topic was discussed extensively at each of the four regional meetings, and it was the subject of several participants' papers. For example, see the papers of Finzer, Hakes, Tobin, Camp, Martin, Brown, Kantowski, Sobel, Fey, Bell, and Hoffman.

Like it or not, the role of mathematics in contemporary society is becoming increasingly important and rapidly so. As science and technology take on ever more importance in our economy, intruding positively or negatively into nearly every aspect of our personal and collective lives, mathematics grows in significance for every citizen. In no other field of study is there a greater need for fundamental change in order to catch up to the times. And in none is the microcomputer such a powerful ally in both inspiring and enabling such change.

6. *To revolutionize mathematics education.* Revolutionizing mathematics education is not one more kind of improvement, but rather an estimate of the cumulative effect of the previously

described opportunities' being fully and imaginatively realized. True revolution in Kuhn's sense rarely occurs in education, but it is not entirely unknown. It probably would be folly to set it as a goal, since the educational system would surely reject any direct effort to change radically its purposes, organization, values, clientele, or methodologies. But it must be cited as an opportunity.

For related views of some of these issues, see the papers by Bork and by Anderson & Clark.

If it happens that there is substantial and steady progress toward individualizing access to mathematics learning, <u>and</u> reaching out to special populations, <u>and</u> introducing radically improved teaching methods, <u>and</u> reforming the mathematics curriculum, then the net effect, seen a decade or two from now, might be truly an American revolution in education. And mathematics will be its first name! Such improvements could occur even if those happenings were unconnected to each other in time or location. If, on the other hand, those reforms do not occur in enough places soon enough, then, viewed nationally, the most that will be seen to have resulted for mathematics education from the "microcomputer revolution" will be incremental and spotty improvements.

WHY NOT MICROCOMPUTERS IN MATHEMATICS EDUCATION?

Given such a menu of attractive opportunities, is not progress inevitable? The opportunities range from enriched instruction and better pedagogy to a revolutionary reconstruction of mathematics education as a whole. Opportunities for improving mathematics education are there for every school, every community, every American.

Nevertheless, it is entirely possible that a decade from now mathematics education will at best be only marginally better. And given today's growing scarcity of mathematics teachers and specialists in the schools, it could turn out much worse. The effects of this scarcity are exacerbated by the declining quality of preparation of those now entering the teaching profession. Teachers, not machines, are the key to quality education in mathematics, and thus it should not be supposed that the microcomputer or any other technology can relieve society of the need to equip schools with talented, well-trained, and highly motivated classroom teachers.

But, good teachers without modern tools are not sufficient either. If we are not to lose ground, if we want to do more than just hold our own or merely get a little better, then awareness of the marvelous technological opportunity before us is not enough. We must aggressively capitalize on the microcomputer revolution in behalf of better mathematics teaching. To do so requires us to acknowledge candidly and deal thoughtfully with the realities of creating innovation in American education.

Teachers' concerns were discussed at all four meetings, particularly at the Boston meeting.

1. *Teachers' concerns.* The acceptance and use of microcomputers in mathematics education will ultimately depend upon classroom teachers. They must come to understand computers--what they can do and cannot do, believe in their value, know how to use them with students, and be willing to change their own practices and perhaps even the curriculum. What fraction of the existing corps of secondary school mathematics teachers and elementary school teachers are likely to reach that position? Consider the difficulties.

Innovation as such--curricular, methodological, or technological--simply does not enjoy a high priority with most teachers. Teachers and parents generally prize knowledge transfer and order in the classroom above all else. Most teachers believe that, given support, what they can do well is teach the content found in the standard textbooks (community-approved via the school board or State authorities) and maintain an orderly classroom in which students can apply themselves to their lessons. There is little need for new content or teaching methods, least of all for "radical revisions." A microcomputer revolution, whatever it is, is one thing; an educational revolution via microcomputers is quite another and surely, most teachers believe, not what either they or the citizens of their communities desire.

See the description of Karlovitz's work, which is related to these points, in the summary of the Washington meetings. Also see Karlovitz's paper.

It is well to remember that persons who develop and promote innovations are usually outside the system they wish to change ("reform") and are rarely classroom teachers. A few teachers ally themselves with the innovators and their projects, but they soon find that persuading very many of their colleagues to follow them is difficult. This is reinforced by the rhetoric of innovation that unfortunately seems to pit teachers against reformers, with the teacher portrayed as "the problem" and the reformers as unrealistic academics more interested in publication than in kids.

On the other hand, Russell a teacher in the Cambridge public school system, noted that some elementary teachers may embrace microcomputers precisely because the machines can handle the noncomputational mathematics (probability, geometry, etc.) that the teachers find difficult. Her paper describes connections between the computer and the use of manipulative materials in the elementary grades.

Naiman's paper addresses the issues of women and "technophobia."

Kastenschmidt expands on these ideas in his paper.

One possible solution to this problem appears in Feurzeig's paper.

Fear of mathematics is a factor that applies especially to elementary school teachers, and also to the increasing number of people who are not mathematics teachers but who are assigned to teach high school mathematics anyway. Many such teachers dread teaching even computational arithmetic let alone more advanced mathematics, and reasonably so, since they themselves were generally victims of a poor mathematics education. If to this fear of mathematics itself is added the uneasiness that many elementary teachers feel with regard to the use of machines, then a computer, seen as a "mathematical machine," becomes doubly fearsome. Very few teachers practicing today have had systematic training in the use of microcomputers, and have no reason to believe they have the ability to become adept with such instruments. The fact that youngsters quickly and enthusiastically take to computers adds to the problem, for most teachers will avoid situations in which they seem to be less able than their students.

Even if the mismatch of priorities between teachers and innovators could be overcome, and elementary teachers helped to suppress their fears of the computer, practical problems still remain. Implementing any innovation almost always requires a teacher to invest time and effort well above normal. Although the claim may be made by its advocates that a particular technological innovation will <u>eventually</u> pay handsome dividends, the teachers know that the work and psychological burden associated with introducing any major innovation will initially, if not forever, exact a high price from them. Given the heavy teaching loads teachers already carry, working conditions which are often demoralizing, and weak reward structures, it is not surprising that teachers are sometimes less than eager to take on the added burdens of change.

Teachers may also perceive microcomputers as the first step in automating education. The thought of replacing people with machines is not an image that appeals to teachers. Nor does the image of youngsters "interacting" all day long with computer terminals and TV screens, isolated from each other and from teachers (except by electronic communication). Such images may be parodies of what advocates have in mind--but what counts is what the teacher believes.

Finally, it must be noted that, one way or another, teachers themselves have a personal stake

Questions of teacher education were also discussed at the Chicago meeting.

in the introduction of new technologies. To the extent that they believe computers threaten their job security, teachers cannot reasonably be expected to welcome them eagerly. Indeed, if teachers see administrators becoming extremely enthusiastic about microcomputers in the classroom at the very time when faculties are being reduced, they will become suspicious about the real motives of the administrators and fight "the mechanization of teaching."

On the other hand, teachers could come to see microcomputers as enhancing their job security. If that technology permeates the classroom despite everything, then those teachers with developed skills in using microcomputers are likely to have more secure jobs. In most school districts, seniority is the dominant, often only, measure of security, but that could change. Furthermore, computer competence in itself is an increasingly marketable skill outside the classroom and may therefore provide teachers further job insurance. Teachers who become really good at programing computers, as many mathematics and science teachers easily do, are already being attracted into industry from teaching. While this may contribute to the decline of the quality of mathematics teaching in the schools viewed as a system, it can be reassuring to teachers as individuals.

See Sobel's paper for further views on the effect of developing computer literacy in students on the shortage of qualified mathematics teachers.

2. *System resistance*. However negatively teachers may respond to the use of microcomputers, one would suppose that "the system" would press for the exploitation of a technology having such great educational potential. School boards and State governments as education policymakers, and superintendents and principals as school administrators, might be expected to view the microcomputer revolution with rather more relish than alarm. Perhaps many do. But there are some realities that can only temper such enthusiasm.

At the Berkeley meeting, Gawronski noted that at least in California, changes in State requirements for tests could be made that would encourage the adoption of new curricular goals, which in turn could promote the use of microcomputers. On the other hand, Hoffman's analysis of trends in mathematics at the Chicago meeting was much less optimistic.

There are priorities to resolve, especially in times of severe fiscal constraint. In most school districts and in most States, innovation of any kind has a weak claim on the budget. Immediate demands--salaries, plant maintenance, fuel, debt service, supplies--take precedence over investment in long-term improvement. There appears to be little or no money left over for changing the system from what it is, technologically or otherwise.

For a related view, see the description of Papert's presentation at the Boston meeting.

The cost of microcomputer-based mathematics education is difficult to estimate at this early stage in its development. It cannot be trivial. The cost per student per year, based on the generous assumption that each child in every classroom in the Nation would have personal access to a microcomputer, is probably very low. The national cost to bring this about would perhaps be no more than 1 or 2 percent of the cost of education in America, a bargain! But in the absence of a Federal investment, local decisionmakers are less interested in "national cost" or in cost per child than in actual cash outlay. They simply have great difficulty in freeing up funds for innovation, bargain or no bargain.

For another view about costs, and how they might be reduced, see Nolte's paper.

The dollar costs, as viewed locally, are either high or unknown. If unknown, administrators will mostly wait until more reliable estimates are available, for they sensibly want to avoid buying into any system that will be far too expensive later, however cheap at the moment. And in fact, is not the cost likely to be high? The microcomputer and assorted hardware may be the least of it. What about the added costs of software and courseware development, testing, and updating? And of equipment maintenance? Of teacher-training? And technical support? If those who control the allocation of local education resources perceive the total costs associated with the widespread use of microcomputers in their school to be high, then we may expect the pattern of adoption to be one of slow and opportunistic accretion.

This was especially evident at the Boston meeting. See also Zamora's paper.

Adeline Naiman, managing director of TERC, attended the Boston meeting.

The pros and cons of standardization were discussed at all the meetings, particularly in Chicago.

Compounding these money problems is the current confusion over choices of machines. Hardware vendors make claims for their equipment, perhaps exaggerated, in a language foreign to most educators. Little trustworthy consumer information is available, and objective nonprofit organizations such as Technical Education Research Centers (TERC), which can provide such information, have great difficulty in staying afloat. Thus it is easy for the schools to wait awhile: wait for standardization to arrive; wait for the newest marvels to come onto the market instead of buying systems that may instantly become obsolete; wait for other schools to do the pioneering and suffer the risks.

3. *Strategic dilemmas.* Even if a groundswell of support develops among mathematics educators for using microcomputers, and funds are

located for widespread incorporation of microcomputers in schools, some fundamental questions of implementation would still remain to confront American education.

First--getting started! The microcomputers themselves seem impressive enough as home use "personal" computers, but less so as heavy-duty school equipment. It takes industrial quality instruments to withstand intensive use by students, something very much more rugged than what will suffice for the individual owner who can be expected to protect his or her investment, or wait for minor repairs. A more serious obstacle still is that software today is very limited in scope, quality, and amount. Not enough good computer teaching materials exist to warrant switching to the microcomputer as a major tool in mathematics teaching. Not many machines will be bought by schools until they are of higher quality and an adequate supply of effective programs exists. On the other hand, with few microcomputers in school use there is no market incentive for potential developers of software or for the hardware vendors to design equipment specifically for school use.

Publishers frequently mentioned marketing problems. For examples, see Harris' paper, and the summary of his remarks at the Boston meeting. See also Marx's paper. And, as Lias pointed out at the Washington meeting, education represents a very small segment of hardware manufacturers' market.

Perhaps the most difficult strategic dilemma has to do with our aims. As one views the opportunities listed earlier for using the microcomputer to improve mathematics education, it can be seen that they range from conservative ("enrichment") to revolutionary (change the curriculum and the methods used to teach it). Selecting a conservative option appears to increase the probability of acceptance. People are comfortable with change that is gradual and familiar and that does not call into question established principles or goals. It is less intimidating than revolutionary change, less costly, and less risky (at least in the short run). Unfortunately, it is also less likely to have a direction, to get anywhere new, or to confront the major problems in mathematics education. Paradoxically, incrementalism may actually <u>block</u> significant change. A conservative strategy could, by using microcomputers mainly to increase the efficiency of current methods and enrich the content somewhat, entrench yesterday's goals, content, and methods more solidly than ever. Mathematics education would then be superficially "modern" without being substantially much different.

Still, attempting to bring off a full-scale revolution in mathematics teaching may result in even less net change. Systems reject out of hand that which threatens, or appears to threaten, their tranquility or survival. Talk of changing teachers into technical consultants, of replacing the textbook as the central instrument of instruction, of deemphasizing rote-based computation in favor of information-based problem-solving mathematics, and the like, may in the aggregate pose just such a threat to mathematics teachers and the education enterprise (including parents, publishers, and politicians). If so, microcomputers as instruments of radical change in mathematics education are likely to be rejected, isolated, or ignored in the United States.

Another strategic dilemma of a very different sort has to do with how the microcomputer can be exploited for mathematics education without at the same time putting the children of the economic underclass at even greater disadvantage than they now experience.

In the noncentralized "system" of education in America, decisions are made in literally thousands of different locations. Those schools or school systems that wish to experiment or to invest in new technologies are usually free to do so if they can afford it. Certain schools seem to like being on the forefront, willingly trying out new approaches and materials. These tend to be schools in wealthy suburban districts near major research universities. Another set of schools includes those that quickly adopt proven innovations because they can afford "to have the latest" and wish to do so.

Innovations stand their best chance of becoming established in these two kinds of schools because of the schools' receptivity, relative financial health, and relative freedom from the tensions and disrupting behavior problems (such as chronic and massive truancy) found in so many inner-city schools. Students in these schools will be the first to use microcomputers in mathematics, and they will be the first to have personal computers in the home. A double benefit awaits them: a better mathematics education than the less privileged and a chance to develop sophisticated computer skills in the bargain.

This was discussed extensively at the Berkeley meeting, although no solutions were offered.

Put the other way around, the narrow implementation of microcomputer-based mathematics education in only a few schools can be expected to penalize the children of our poorest citizens, unless an imaginative and explicit strategy is worked out to include them in our implementation decisions. The already poor will become even poorer, in spite of our slogans about equal educational opportunity, in spite of the personal and societal costs that will follow, and in spite of the possibility that this new technology could be an especially powerful tool for raising the mathematical and computer skills of all Americans.

SOME POSSIBILITIES FOR ACTION

Our main purpose in this essay has been to provide a framework for thought and action. We have tried to provide a balanced view of the potential that microcomputers have for improving mathematics education across the United States, yet at the same time to be realistic about the impediments to the full and imaginative exploitation of this new technology. As we see it, the opportunities are captivating and the problems formidable. All things considered, cautious optimism would seem to be in order.

But now what? Knowing what the difficulties are does not guarantee knowing what to do about them. As we said at the outset, this is a time for action, for movement. Microcomputers pose the possibility of a new agenda in mathematics education. A new agenda in mathematics education for America is a call for leadership in all segments of our society--public, corporate, professional, and governmental--in improving the quality of mathematics education in America. In the face of the diversity and fragmentation of American education, a new agenda is a call for commitment to innovation at all levels. It is a call for cooperation and trust among all who have a role to play. What follows are suggestions of some possibilities for action and indication of where leadership, commitment, and cooperation are needed. The intent of the suggestions is not to provide pat solutions but rather to stimulate discussions of strategy across the whole of American society.

1. *Rapidly increase a realistic demand for microcomputers among teachers of mathematics in junior and senior high schools.* More and more teachers are becoming interested in microcomputers. Workshops designed to inform teachers on the educational uses of this new technology are typically oversubscribed, and computer presentations at professional conventions are well.

Isaacs discusses related points in his paper.

attended. Teachers who do experience a good 2- or 3-day intensive workshop are generally enthusiastic about microcomputers and look foward to having one or more in their classrooms. But the opportunities for such exposure are limited and the number of mathematics teachers in this country is large. Thus the total number of mathematics teachers who have more than a casual knowledge of the potential value of microcomputers for teaching is still quite small.

Only if teacher demand grows can the actual purchase of microcomputers for mathematics be expected to increase. As the fraction of mathematics teachers who have access to classroom computers grows, the demand for microcomputers should increase further. The net effect could be exponential growth in demand for a period of years. Thus, pump-priming now to build up demand to a critical level might very well create the market conditions necessary for hardware vendors and software developers to pay serious attention to school needs.

Mathematics teachers are not going to want microcomputers in their classrooms until they know more about them. Seeing to it that mathematics teachers have opportunities to become informed on the nature and uses of microcomputers is a task that might be undertaken by the National Council of Teachers of Mathematics and other professional societies. It would involve:

Other professional societies were identified in the summary of the Boston meeting. A Presidential Commission on scientific and mathematical education was mentioned at the Chicago meeting as having been proposed by the Council of Scientific Society Presidents.

- Promoting awareness of the potential of microcomputers in mathematics with presentations at local, State, and national meetings, and by soliciting more good journal articles. Awareness must be even broader, however, for parents, teachers, administrators, school boards, unions, the private sector, government, and the mass media need to become informed on the unique role of mathematics in a technological society and on the potentially revolutionary aspects of the personal computer (alone and in conjunction with other technological advances).

- Persuading qualified individuals in schools, colleges, and universities to conduct workshops for teachers of mathematics in junior and senior high schools. Experience indicates that teachers or their school districts will pay reasonable fees to attend. Microcomputer companies will generally participate. Thus the chief problem is not, for a change, financial. The mathematics associations could provide models of successful workshops, put potential workshop directors in touch with vendors and publishers, and help publicize the workshops.

- Serving as professional clearinghouses for school districts that wish to have microcomputer training for their mathematics teachers on the school premises during the academic year.

- Convincing colleges to offer summer courses for teachers and educational administrators on the use of microcomputers, with special emphasis on learning how to write programs for mathematics teaching. We must create opportunities for teachers and their administrative superiors to keep current with "mathematics via microcomputers." Formal continuing education of teachers and administrators in the microelectroric age must be part of the new agenda for State certification agencies, professional associations, school administrations, school boards, teachers unions, universities responsible for teacher preparation, and the microelectronics industry. What should be the new certification standards? What incentives should be enacted? When do you provide the training? Who finances the enterprise across all 50 States?

Some specific proposals for linkages between education and industry were made in Chicago.

2. *Increase the quantity and diversity of supplementary but exemplary mathematics microcomputer programs.* Exemplary programs are necessary if demand is going to be generated and then sustained. The important requirement is that the pool of high quality, imaginative, and relevant programs be increased. The need is for a rich supply of programs that go far beyond simple drill and practice and that emphasize mathematical thinking.

See Hughes' paper for a challenge to mathematics educators from computer scientists to produce prototypes of high quality.

. As mathematics teachers learn how to use microcomputers in ways that surpass what is possible with traditional techniques, they may begin to look for and even develop more ambitious and integrated uses of microcomputers in their classrooms. Once teachers experience the power of

See Finzer's paper for some specific ideas related to this point.

computer simulations, meaningful games, the use of real-world data, and the like, to motivate, accelerate, deepen, and extend student mathematical understandings and skills, they will be better prepared and willing to reexamine the entire mathematics curriculum. Also, the availability of more high-quality programs, even if supplemental, will help stimulate increased teacher demand.

How to develop such microcomputer programs, publicize them, and make them available to mathematics teachers is not at all clear. Certainly professional associations could play a key role. Influencing publishers, identifying and encouraging talented program developers, advertising good products in journals and at conferences, and helping to build networks are all possibilities.

The matter of support from specialists was particularly stressed at the Boston meeting.

We must also begin a new tradition of providing formal systems of professional support for our mathematics teachers. If teachers, novice and expert alike, are to be able to use the microcomputer in the mathematics classroom as a standard tool of instruction, they must have specialists to turn to. Not only must they have access to specialized knowledge--about the idiosyncrasies of the machine or details of the teaching program--but the access must be timely. School administrators and policymakers, industrial producers of microcomputers, publishers, curriculum developers, testing companies, creators of existing support networks (e.g., CONDUIT), and teachers must begin to work out the geometry of responsibilities.

Related to this, see the discussion of hardware in the summary of the Washington meeting. Zamora's paper is also concerned with the construction of hardware. An alternative view is expressed by Marx, who describes computer hardware as "somewhat indestructible." See his paper for details.

3. *Quality standards for microcomputers and microcomputer programs in mathematics should be established and promulgated.* Machines of any kind need to be designed and built in the light of the circumstances of their intended use. School use is different from either home or industrial use. A microcomputer that is going to be used in teaching elementary and high school mathematics must be constructed to withstand hours of continuous use by hundreds of different operators, most of whom are untrained and none of whom owns the machine. Ease of maintenance is especially important, since few schools have electronic technicians available. Computers designed for hobbyists or personal use in the home probably are not rugged enough for extended school use.

It should be possible to convene a group of experts, including mathematics teachers who are veteran users of microcomputers in the mathematics classroom, to draw up specifications for operating standards. These performance specifications would have to be transformed into manufacturing requirements. Once the equipment standards are agreed upon by mathematics teaching associations, scientific societies, electronics manufacturing associations, and other appropriate groups, a plan to bring those standards to the attention of State and local purchasing officers could be developed as a cooperative undertaking by the interested associations.

One such group is the MicroSIFT project at the Northwest Regional Educational Laboratory. Its director, Judith Edwards, described this project at the Berkeley meeting and in her paper.

Some participants at the Berkeley meeting felt that there is a danger that standards of taste in software might descend to the level of those in commercial television programing.

The task of establishing software standards is much more difficult. Some groups have made progress already in outlining the steps that teachers should use in the process of selecting programs for student use. As these are perfected, they should be widely and continuously disseminated by appropriate scientific and teaching societies. In addition, a national reviewing process and publication analogous to Consumer Reports or Science Books and Films could help identify those mathematics programs meeting the highest content standards and provide unbiased descriptions of them.

4. *Promote the flow of microcomputer resources for mathematics teaching into the schools serving disadvantaged children.* Federal funds to improve the education of children from poor families, minorities, and the handicapped reach the schools either directly or through the States, along with a percentage of funds from State budgets. Given the crucial importance of both mathematics and computer competency to the future of those youngsters, the appropriate State and local authorities ought to be persuaded to dedicate a suitable fraction of those funds to the use of microcomputers in the schools serving them. Working with representatives of the special populations, the science and mathematics communities, through their professional societies, should try to influence the allocation of title I and other such funds to this end.

5. *Increase the national investment in research and development related to the use of microcomputers in learning mathematics.* If the steps noted above are vigorously taken, by the end of this decade we could expect a relatively large number of mathematics teachers to be using

microcomputers. The quality of the machines and programs should have improved, and hence mathematics learning itself. But even if so, the total impact will have been limited in extent and depth; mathematics education might be richer and more fun but not much different in content or thrust.

In his remarks at Berkeley, Kee stressed the need for communication between basic research psychologists and software developers.

For a description of some experimental work in the area of machine-human interactions, see Friedie's paper.

This was especially emphasized in the Berkeley and Washington meetings.

Thus, at the same time that the ground is being prepared by creating teacher demand and experience and raising standards, other steps need to be taken to exploit the new technology more profoundly. We must increase our knowledge of how mathematics is learned with and without machines and of how microcomputers can best be used to extend and amplify the human intellect. Scientific research, basic and applied, is as central to the improvement of mathematics education as it is to any other modern enterprise. We must also look anew at the mathematics curriculum through the eyes of the microcomputer. Our technological age calls for curriculum renewal. It is not too early to begin a complete reexamination of the mathematics curriculum, kindergarten through high school, in the light of our understanding of the human mind and the full potential of the microcomputer (alone and in combination with other devices).

Research and development activities are well within the capabilities of many institutions. Typically, funding has come from Federal agencies, in particular the National Science Foundation and the National Institute of Education. Mathematicians and teachers should bend every effort to see that this essential Federal responsibility is continued and even increased. But responsibilities extend also to other sectors of American society--industry, foundations, and State governments. They, too, must participate in the betterment of mathematics education in America through research and development.

NSF-NIE REGIONAL MEETING IN BERKELEY

June 14-16, 1981
Diane Resek

ANNOTATED AGENDA

Sunday, June 14
7:00-7:20 p.m.: Introductory remarks
Edward Esty, National Institute of Education

Dr. Esty explained that the meeting was to serve two purposes. The first was to allow project personnel to present their projects and to receive feedback. The second was to talk about issues relating to technology in mathematics education around the theme of the Agenda for Action of the National Council of Teachers of Mathematics. The specific theme for the Berkeley conference, the first of the four regional meetings, was informal versus formal learning.

7:20-7:40 p.m.: Slide show
Dorothy Deringer, National Science Foundation

Dr. Deringer stated that the time had come to go beyond goals tc plans for the improvement of mathematics education using technology. She expressed hope that this meeting would produce some plans, and presented a slide show of NSF projects as an overview to work in the area.

7:40-8:30 p.m.: Demonstration of curricular materials
Alfred Bork, University of California at Irvine

Dr. Bork showed three programs from his informal science literacy project. The programs stress discovery learning in a controlled environment, since they are intended for use in informal settings such as libraries and museums where assistance from teachers is not available. The specific content areas were Battery and Bulbs, Optics, and a version of the game of Life.

Monday, June 15
9:00-9:45 a.m.: Demonstration of the Mathematics Network Curriculum Project
William Finzer and Diane Resek, San Francisco State University

This project is creating materials which integrate computers into the formal middle school curriculum. There is a training program for teachers using the materials, and a computer network for interclassroom communication. The materials demonstrated a program by which users guessed the nature of strategies used by several players for the game of Nim. A second program allowed users to program the computer to play Nim according to some strategy. The programing language was the language of algebra, so that users could experience "speaking algebra" as a useful means of communication.

9:45-10:15 a.m.: Demonstration of programs to teach about calculators
Arthur Kessner and John David Miller, Lawrence Hall of Science

This project was begun in response to the underutilization of calculators in the schools. The project trains teachers through computer programs which are set up in informal settings (such as teacher lounges) to use calculators to help students understand basic mathematical concepts. The two computer programs presented show the use of calculators to teach counting and to teach place value.

10:20-10:45 a.m.: A Developmental Psychologist Looks at Computers
Daniel Kee, California State University at Fullerton

Dr. Kee raised several issues that were of interest to him as a psychologist. The first was the potential of microcomputers in working with two kinds of adults: mathophobic college students (to help them feel more confident in the area of quantitative analysis) and elderly persons (to enrich their lives and bridge the age gap). The second issue was that better communication is needed between basic learning researchers and software developers so that we can understand effects of computers on users in areas such as the expansion of working memory. The third issue involved the effect of computers in the home on children, particularly if there is no computer expert present in the home.

10:45-11:10 a.m.: Peer Teaching and Microcomputers
Marc Swadener, University of Colorado at Boulder

Dr. Swadener described a project in which high school students tutor elementary school students using microcomputers. Although hard data on the project are not ready, the soft data, especially relating to absenteeism, are very favorable.

11:10-11:35 a.m.: Lessons From Electronic Game Parlors
Brenda Laurel, ATARI Corporation

Dr. Laurel noted that the intense popularity of electronic games may have lessons to teach us about the use of computers in education. The games provide personal power and personal freedom for the user and, traditionally, both concepts are alien to educators. In addition, the addictive games have kinesthetic components, and a number of games require sensory awareness (such as a red screen for red alerts) as part of the learning strategy. Dr. Laurel mentioned with concern that girls rarely use the parlors and that these games can be more insidious than television. Both of these issues were discussed throughout the meeting and are discussed in the second part of this report.

11:35 a.m.-12 noon: ComputerTown, USA!
Ramon Zamora, People's Computer Co.

The goal of ComputerTown, USA! is to saturate the local community with soft computer literacy (i.e., knowledge about availability and basic familiarity with microcomputers) and to help others outside the area start similar projects. ComputerTown works with libraries, senior citizen groups, clubs for teenage boys, schools, and so forth.

12:30-12:50 p.m.: Microcomputer Use in San Diego County Schools
Jane Gawronski, San Diego County Department of Education

Microcomputers are being used in the county mainly for instructional games, drill and practice, and to teach programing. Dr. Gawronski feels that, given the increased availability of microcomputers, it is important both to change the mathematical content (e.g., substitute new content for long division) and to change our methods for teaching old content areas. She feels changes are possible in California since teachers tend to teach to the State tests, and the tests are based on the State framework, which can be changed.

12:50-1:10 p.m.: Potential Impact of Computerized Information Rétrieval Upon Mathematics Education
David Moursund, University of Oregon

Dr. Moursund characterized present mathematics learning as occurring in three areas: learning facts, training the brain in routine symbol manipulations, and high-level thinking. He predicts that people will need to learn fewer facts, as they can look up information on a computer; that they will use computers or calculators as aids for tasks in which they now use paper and pencil; and that much higher level thinking that we now do will be done by telling computers the problem in the English language.

1:10-1:30 p.m.: Mental Errors in Arithmetic Skills: Their Diagnosis and Remediation in Precollege Students
Harold Miller, WICAT, Inc.

This project is categorizing computational bugs for whole number subtraction and decimal and fraction addition. Project researchers have found that certain bugs are more common than others, but that the bugs an individual student has change over time. In fact, a student who has a bug on the first test will probably show a bug on the second, but the second bug will be different from the first. The project is also trying to see if human teachers are more, less, or equally as successful as computers in finding and in remediating students' bugs.

1:30-2:00 p.m.: Demonstration of precalculus materials
Edward Landesman, University of California at Santa Cruz

Several years ago, in an attempt to accommodate a more diverse student population in calculus courses, Dr. Landesman made 80 10-minute video tapes to supplement lectures. He then made some noninteractive computer programs with color graphics for the same purpose. He is currently developing interactive programs. He was able to show an example from the first two series, but the third series is still in progress.

2:00-2:30 p.m.: Demonstration of materials for Pueblo students
Judith Hakes, All-Indian Pueblo Council

Dr. Hakes is developing science and mathematics units for fifth grade Pueblo children, to be compatible with their culture. Each unit begins with a story, since stories are the traditional communications media for Pueblos. The stories are followed by a game, which in turn is followed by an activity using the game scores. The story, game, and activity are all presented on a computer using sound. Since competition is taboo in Pueblo society, Dr. Hakes developed a cooperative activity to graph the game scores. One student controls the x-coordinate of the square to be placed in the bar graph, while a second student controls the y-axis.

2:30-3:00 p.m.: Demonstration of materials in statistics
Ronald Saltinski, Dixie School District, San Rafael

Dr. Saltinski is developing a course on statistics for middle school students. In the course, students use statistics and graphics packages to represent and analyze data. He reported that sixth graders are quite comfortable using χ^2 tests. He also reported that students taking this statistics with computers course did markedly better on the State statistics test than other students in the district who learned to represent and analyze data by hand.

3:00-3:30 p.m.: Presentation on the Order of Magnitude Training Effect
Wallace Judd, Apple Computer, Inc.

Dr. Judd showed part of a presentation from the heart association on cardiac pulmonary resuscitation (CPR) which used a computer, videodisc system, a random access sound system, and a dummy connected to the computer. The computer program gave feedback to the learner as the learner worked on the dummy. Via the videodisc, the learner could also witness a real situation where CPR was needed. Dr. Judd stated his belief that the computer alone will not be th important educational tool of the future; rather, the important tool will be the computer coupled to videodiscs and other devices.

3:45-5:30 p.m.: Group discussions

The participants worked in two groups: one on education in formal environments and the other on education in informal environments. The group goals were to identify two or three important changes needed for computers in education over the next 5 years. Then they were to produce a timetable for those changes and to determine the groups who would be responsible for implementing them.

Tuesday, June 16
9:00-9:30 a.m.: Continuation of group discussions

9:30-10:15 a.m.: Demonstration of materials for young children
Teri Perl, Advanced Learning Technology

Dr. Perl demonstrated materials designed for second and third grade gifted children in the areas of logic and geometry. The first program had a carefully structured sequence of Hurkle and Tic-Tac-Toe games to impart graphing skills. Next, she showed an adaptation of Bill Budge's graphic package which is being used to teach geometry. Last, she showed a program in which students hook an animated boot to a system of logic gates so that the boot will kick passing ducks. The ducks and the boot live in a complex of rooms.

10:15-10:45 a.m.: Presentation on evaluation of software and courseware
Judith Edwards, Northwest Regional Laboratory

Dr. Edwards described MicroSIFT (Microcomputer Software and Information for Teachers), a project which evaluates software and will disseminate the evaluations to teachers. Each evaluation consists of reports from two classroom teachers and a computer specialist. MicroSIFT has developed an evaluation form for software but has not yet decided how to disseminate the evaluations.

11:00 a.m.-12:15 p.m.: Reports from the discussion groups

The informal education group formulated a timeline for change in five areas: software, evaluation, new environments, research, and education and industry.

1982

1. A task force should be formulated on models for cooperation.

2. Research should begin in the uses of color and sound with computers and in applied research linking the cognitive sciences with computer education.

1983

1. Find out what will appeal to women and other people who are not presently interested in computers.

2. Develop evaluation models that nontechnical people will understand.

3. Look at the possibility of developing courseware ideals or standards.

4. Develop a combination of ComputerTown, USA! and the Education Development Center (EDC) where people can pay to learn specific topics using computers.

5. Develop a mechanism so that universities can give credit for computer learning.

1984

1. Big business will be very strong in home education, so educators must have developed ties with them so that their influence will be present.

2. There will be continuing education courses for scientists and engineers.

1985

1. We will no longer think so much in terms of programs, but in terms of software components which serve as building blocks for learning environments.

2. Faculty must be reeducated and we must remember that adults don't learn in the same way children do.

3. Low socioeconomic groups will need help to keep from being left out of the computer age.

4. Industry will provide home education environments as fringe benefits.

5. We will need better tools for children to create computer environments.

1986

1. Computer literacy will no longer be a problem for white males.

2. Children will be computer professionals.

1990

1. Computers will speak English so people can program in English.

The formal education group discussed the changes needed in formal education and the past difficulties of effecting any changes. It became clear that mathematics education must put less emphasis on algorithms, but it was not clear as to what other topics need to be incorporated and what will become important in the future. How teachers at the elementary level through the university level can be retrained seemed to be an insurmountable problem. The Government might foster some change by developing test banks with items that will stress understanding rather than rote skills. Much time was spent discussing the question of women and computers and whether there is a special problem and, if there is, how to deal with it. No conclusions were reached.

CONFERENCE ISSUES

Most of the issues that came up at the conference fell into two categories: use of computers in education and computers in society.

Use of Computers in Education

There were five categories of issues in this area: appropriateness, research, software needs, teacher education, and funding.

Appropriateness

Probably the subject of strongest disagreement among participants was the extent to which computers are better teachers than humans and the areas where computers are best used. Research in this area seems to be sorely needed.

Participants felt that it is better for children to learn directly from working with some materials than from exploring the materials through a computer simulation, e.g., batteries and bulbs. However, few teachers use these materials since they involve work to set up and clean up and a less orderly classroom. Thus, the question arose whether it wasn't better to use computer simulations than for students to have no exposure to the materials.

Participants agreed that the mathematics curriculum will and should change in the new computer age; however, they disagreed on the extent of change (e.g., no computational skills taught at all versus less time on complex algorithms such as long division) and the new material that should replace deleted curriculum topics.

Research

There was general agreement that applied research was needed and that such research should involve interdisciplinary teams of researchers if we are to get reliable answers to real research questions which are applicable to real-world school settings. However, it was acknowledged that it is difficult for people from different disciplines to work together, given their different orientations and vocabularies.

One area in which research is needed is in determining the use of color and sound with computers. Where is it distracting and where is it useful?

Perhaps the research issue that prompted the most controversy was sex differences in the use of computers. Many participants felt that young men were using computers and were far more enthusiastic about them than were young women. Some others felt that there may have been past problems with young women and mathematics but that these problems were disappearing. Still others felt that although many young women were not interested in computers, some young men were not either and that it was not a sexual issue; rather, it was an issue based on another dichotomy. One suggestion for that dichotomy was Witkin's global/articulated personalities.

Among participants who felt there was a problem with young women and computers, there was disagreement about the directions in which the solutions lie. Some felt the problem was a psychological one and would require psychological treatments. It was suggested that NLP (neuro-linguistic programing), Gestalt therapy, or Shelia Tobias' work with mathophobia might hold some answers. Others felt the problem lay in the differing interests of young men and young women and the fact that most computer activities deal with young men's interests. Their solution was to determine the interests of young women and write programs to interest them.

Software Needs

Many people saw a need for graphic tools that professional artists could easily use. In addition, some participants felt that good tools were needed so that teachers and students could easily set up computer learning environments.

Teacher Education

There was general agreement that we need better trained mathematics teachers, and that teachers will need training to use computers well. There was a feeling of hopelessness about trying to accomplish this goal. It was acknowledged that some work must be done with university education departments. Some participants felt that expertise would develop naturally in the departments, while others felt it would be a difficult process.

There was much concern about finding good methods to disseminate software information to teachers. Some felt that electronic networks might be the answer.

Funding

There was concern about how educational uses of computers, especially creative software, would be developed in the future, particularly in light of reduced Federal funding. It was hoped that educators could learn to work with industry despite severe communication problems. Hardware, software, and data base developers were seen as funding sources. It was also suggested that organizations like ComputerTown, USA! could be self-supporting or even profit making and would support development at least for home use of computers.

Computers in Society

There were three categories of issues in this area: widening gaps, education and home use of computers, and responsibility.

Widening Gaps

Many participants felt the home use of computers would widen the gaps in the acquisition of key skills between upper and lower class young people and between young men and young women. There were no solutions suggested for lessening this effect on the gap between classes, which would occur when poorer people would not be able to buy home computers, while middle class families would.

Education and Home Use of Computers

Some participants felt the home use of computers and growing sophistication of computer-assisted instruction might supplant all of the traditional functions of schools except the social ones. Others felt the effects of home use might be less extreme but schools would need to take into account the new skills young people would be acquiring at home. Some participants felt that the constant use of exciting computer games at home would turn students off from the relatively boring school programs. However, the experience of the University of California at Irvine group has been that students' interests in their programs are relative to immediate alternatives. Thus, students at the Lawrence Hall of Science are not very enthusiastic, whereas students in classrooms are.

Responsibility

Much current software deals with violent themes and involves a great deal of competition. Many participants felt this was inappropriate. In addition, if industry takes over funding for software, there was a concern that the level of taste in software would rapidly descend to the level of taste in commercial television programs. (One participant felt we would have greater variety in computer software than in television programs since the former are cheaper to produce.)

A major theme in the conference was who is responsible for values and taste in software, as well as who is responsible for the creation of high-quality educational software, the education of teachers, the development of compatibility among computer systems, and so forth. Most participants felt that mathematics educators are responsible for the values implicit in the software they create. A minority felt that we are educators and not social reformers; hence, we must accept cultural norms as given. It was suggested that the Federal Government, State governments, local school districts, professional organizations, and industry all had some responsibility in these matters. However, the conference was unable to assign definite roles. In addition, few ideas were suggested to help make various organizations aware of their responsibilities.

NSF-NIE REGIONAL MEETING IN CHICAGO

June 28-30, 1981
Lynn Arthur Steen

Discussion at the Chicago regional meeting took place in an atmosphere heavy with awareness of the fragile relationship between the scientific and educational communities and the Federal Government. Just 2 days before, the House of Representatives in a strategic maneuver had removed all NSF programs from the FY 1982 budget bill. Even though this action was just the first step in a long budget battle, it vividly focused this conference's attention on the need to rethink traditional verities concerning support for innovation in public education.

Participants at the Chicago meeting were divided quite evenly among the many groups interested in the problems of mathematics education and computer technology--teachers, publishers, hardware manufacturers, project directors, and specialists in mathematics education. This mixture of diverse interests produced vigorous debate, and revealed some deep-seated divisions that make true cooperation difficult. Overall, the problems presented outweighed the solutions proposed by a wide margin.

CURRENT ISSUES

Mathematics Education

For years two issues have dominated the public's image of school mathematics: declining test scores, and the fiasco of "new math." Now two new themes are emerging: the need for emphasis on problem-solving rather than on mere computational facility, and the sudden widespread perception of a "crisis" in school mathematics.

Problem-solving is put forth by the National Council of Teachers of Mathematics (NCTM) in An Agenda for Action as a counterbalance to the "back to basics" movement, itself a public expression of dissatisfaction with the "new math." Important as this shift in pedagogical emphasis may be to professional educators, it is not the issue that has stirred public interest. The recent public alarm about the "crisis" in mathematics education stems primarily from issues of quantity rather than quality: Not enough students are taking mathematics in school, not enough mathematics teachers are being trained to meet the needs of public education, and not enough is being done with the mathematics curriculum to meet the needs of the new technology.

These issues were joined at the Chicago meeting by Max Bell, professor of mathematics education at the University of Chicago. Bell argued that for 90 percent of our citizens mathematics education has been largely a failure. Most of the Nation's 2 million elementary teachers do not understand mathematics, so they waste half of a student's best school years in a "stupid" emphasis on elementary arithmetic facts. This misplaced emphasis is reinforced by textbook publishers who choose to publish what teachers feel comfortable with, and now by computer vendors who promote "drill and practice" software because that happens to be easy to program.

Bell elaborated on NCTM's proposals by outlining appropriate objectives for school mathematics. Instead of emphasizing such things as mixed fractions and long division--topics which now frequently occupy nearly 2 years of school learning--Bell talked of confronting numerical information, fondling data, selecting appropriate operations, estimating results, and approximating answers. These are fit topics for a computer age, topics that will enable children to grow up as masters of the machines of modern technology rather than as their slaves. Yet neither Bell nor anyone else at the meeting was optimistic that these new topics would quickly penetrate the public school curriculum.

Ruth Hoffman of the Mathematics Laboratory at the University of Denver examined trends in mathematics education from the viewpoint of a hypothetical observer in the year 2000. Her conclusion: Despite numerous fads that caused minor perturbations, the mainstream of mathematics education has changed very little in the last century. School mathematics in 1980 differs from school mathematics in 1900 primarily in trivia: bigger books, color printing, calculators, tear-out worksheets, and now, perhaps, computers. The lesson of history is that the school mathematics curriculum is remarkably resistant to change. There is little evidence that NCTM or NSF or computer conferences or anything has sufficient power to bring about major change in school mathematics.

Computers

The role of computers in education is not yet as well established as is the role of mathematics, so it is not surprising that there is more disagreement concerning it. Ludwig Braun of the Department of Electrical Engineering of SUNY at Stony Brook called the computer an "amplifier of the intellect," thus supporting the notion that it could create, if properly used, a revolutionary impact on education. Sid Nolte of Texas Instruments (TI), on the other hand, argued from plausible technological and economic projections that it could take as long as 20 years to put even one microcomputer in every classroom in the Nation. He suggested that educators must first prove that computers can produce better education before the public will stand the expense of providing sufficient computer technology. Despite this lack of public support for major technology expenditures in public schools, TI's experience shows that there is an intense consumer demand for educational devices. Nolte's report thus called attention to one of the key issues concerning the role of computers in education--whether the locus of activity will be in the home or in the school.

One handicap facing the school is that the explosion of microcomputer technology has created a chaotic environment that makes curriculum adaptation and teacher training very difficult. Teachers, developers, and vendors alike bemoaned the lack of transportability of software, the incompatibility of hardware, and the constantly changing technology that makes both textbooks and teachers' knowledge obsolete before they can be put into practice. Of course, it is precisely the constant change in technology that has created the computer revolution. So the emphasis in these discussions was not on suppressing this change, but on encouraging cooperation, disseminating information, and providing support services for those (especially teachers) who most need it.

Several individuals outlined possible scenarios for microcomputer development during the 1980's. Most agreed that programing standards would improve (presumably because they could hardly get worse) by increased attention to modular design, to program recognition of user errors, and to careful design of the computer-human interaction. The optimists believed that high standards of programing quality would be common by the end of the decade; the pessimists doubted if the extent of bad programing would ever diminish. All agreed that for a period of 5 to 8 years those who sought to promote the use of computers in education would be operating as missionaries in a skeptical environment, waiting for computer software to become good enough to take root as an indigenous part of the educational environment.

On two important issues, however, there was considerable (and perhaps surprising) disagreement: transportability of software and compatibility of hardware. Some believed that these are desirable ends that will be achieved near the end of this decade; others believed that, however desirable they may be, market forces would prevent their attainment; and still others believed that they were not desirable--because they would stifle creativity--and should not be specially encouraged. James Johnson of CONDUIT discussed the objectives as well as the difficulties inherent in CONDUIT's effort to provide software in a transportable BASIC, and Gerald Isaacs of the Department of Computer Science at Carroll College advocated development of very high level languages that could be translated into, for example, various BASICS, by special translation programs.

Yet despite these efforts to achieve harmony, the marketplace is dominated by cacophony: color here, sound there; high revolution graphics here, voice synthesizer there. Each machine has unique capabilities, so good programers will design programs to show off these special features. The variety produced in this environment is what fires the imagination of young programers and keeps the field dynamic. Ludwig Braun argued that a move toward compatibility and standardization would be at the expense of variety: Such a trade would not be wise at this point in the development of computer technology.

The commercial publishers and vendors who attended the Chicago meeting helped focus discussion on certain special problems that they perceived to be impediments to their development of appropriate products. Foremost among these is their concern over electronic copying of software: So long as individuals can copy software for entire classes or schools, there will not be sufficient economic incentive for publishers to make high-quality material available. On the other hand, it is contrary to the nature of good education to simply use black-box programing, so any reasonable environment for computer use must permit local adaptation of software, and this requires an ability to copy programs. The conflict between these two goals appeared unresolvable.

A second concern, one that divided publishers from manufacturers, is over the rapid pace of hardware change compared with the relatively slow pace of textbook and software development: the manufacturers' rush to replace older products with new ones leaves publishers holding the economic bag full of outdated materials and reduces teachers and administrators to a state of frustrated confusion. A commitment to upward compatibility on the part of all hardware vendors would go a long way toward solving this particular problem.

The premise of these NSF-NIE conferences is that new technology, especially computers, should influence the nature of mathematics education. Most people feel that inspired use of computers could improve mathematics education, and conversely, that mathematics education might become an anachronism if it ignores the reality of the computer revolution. NCTM stipulates in An Agenda for Action that mathematics programs should take full advantage of the power of calculators and computers at all grade levels. Yet the evidence of NCTM's PRISM Project suggests that public support of this item may be weak: Calculators are definitely perceived as yet another excuse for not teaching the third "R," and to the extent that computers are used in the same way they may be similarly tainted.

There is, however, considerable public support for introducing computer literacy into the school curriculum, and in most instances this seems to be suggested as an addition to the mathematics area. That mathematics has become the school sponsor of computer literacy is perhaps an outgrowth of the widespread fear of computers among those who are not well versed in mathematics.

It is not clear whether the addition of computer literacy will help or hurt mathematics education. To the extent that it introduces students to algorithmic ways of thinking, and encourages them to explore the potential of the computer as a mathematical device, it will certainly open up new avenues into advanced mathematics. But if it sits on the side of the main curriculum, and is substituted for regular mathematics in the schedule of student electives, then it may simply accelerate the slide that has plunged mathematics education into its current crisis.

Whatever way computers are used in mathematics education--whether to teach computer literacy or to help teach mathematics--it is essential that teachers be provided appropriate training and support. This is probably the single most important and most difficult challenge posed by this conference. One of the failings of the "new math" movement was that it did not recognize the magnitude of insecurity and fear that these new ideas generated among those (teachers and parents) who were not sufficiently well trained in mathematics. The same is true of computers: Even mathematics teachers may have a significant problem in overcoming their fear of the computer. The task of reeducating millions of teachers is enormous, and seems at this moment to be beyond the political and economic will of our Nation.

Teacher training is needed because the computer is new, as it was needed when the "new math" was new. But the computer carries with it two major additional characteristics that can undermine the efforts of even the most adventuresome teacher. Because bright students almost always learn to program faster than their teachers do, every teacher will be faced with students (from grade 5 and up) who know more about computers than they do. This can be an unsettling experience, reinforcing the insecurity about mathematics and computers that has led to such ineffective and disastrous education in the past. Moreover, the computer is several orders of magnitude more complex than other educational technologies--film projectors, overhead projectors, televisions. So when things go wrong, it is very unlikely that the teacher (or even a bright student) will be able to fix it. One or two bad experiences in which a class period is destroyed by a disc that won't read or a program that won't respond is enough to undermine all the public relations and teacher training that the computer industry can provide.

Dorothy Strong, director of the Mathematics Bureau for the Chicago Board of Education, warned participants that the microcomputer may suffer the same fate as the "new math" if those who are promoting its use do not adequately cement relations with all the appropriate special interest groups--teachers, unions, parents, and administrators. She said that the experience in Chicago has not been altogether positive: Too often high pressure salesmen have pushed hardware or software because they needed to sell it, not because it was really beneficial to the curriculum or to the students. She cited as examples the excessive emphasis on drill and practice in current software, and the emphasis in some packages on individualized classroom management at a time when this practice is no longer in vogue.

One final observation concerning the effect of computers on mathematics is worth special note. For many years now mathematics educators have been working hard to reverse an extraordinary male-female inequity in school mathematics that was foreclosing from scientific and technical careers many of our Nation's brightest young women. Pilot programs in major cities, special action from NCTM and MAA, and a slowly spreading sensitivity in the publication community to sexist language in mathematics books are having a salutary effect on this problem. However, numerous observers have pointed out that the computer seems to be reversing this trend: When left to their own devices, young boys outnumber young girls by factors of about 4:1 in exploring computers and progressing to advanced programing levels. Some believe that this may be caused by the nature and popularity of computer games which, after all, were developed by white male engineers. Certainly something must be done to insure that the computer does not become an instrument for social or sexual inequality simply because it is designed to appeal to individuals with the same attitudes and training as its designers.

PROPOSALS

Teacher Training

Without question the most important task facing our Nation in the area of mathematics and computer education is to train and retrain approximately 2 million teachers. It is not clear that the job could be done well even if there were sufficient funds to support it (approximately $2 billion). But in the present climate of eroding tax support for public education, it is indeed a utopian vision. Without it, Max Bell predicted, we will continue to fail to teach mathematics, and once again relegate a generation of school children to archaic and irrelevant hours of frustration that produce more fear than competence, more hatred than understanding.

There are two fundamentally different avenues that might lead to this goal of teacher training and support: public policy leading to increased tax support for public education, and linkages with industry leading to private capital's being used in imaginative and creative ways for the benefit of public education. Both approaches are needed, for neither alone can possibly accomplish the job.

Public support for mathematics and computing is essential to any successful venture in public education. The general public--your next door neighbor, not your colleague at the office--needs to be convinced of the benefits of introducing computers in education, and must be persuaded that mathematical and computer literacy is an essential component of basic education in this age. Participants suggested that one means of accomplishing this might be a national commission whose purpose is to convey the urgency of this message in the broadest terms and at the highest levels. (The Council of Scientific Society Presidents has recently made a similar proposal, for a Presidential Commission on scientific and mathematical education.)

The need to reach mass audiences suggested to several participants that television was an appropriate and essential medium of communication. It could be used as a vehicle of public information (and public relations) by slanting computer and high technology advertising to promote the value of mathematics education rather than merely the image of the sponsoring corporation. It could also be used as a means of reaching the millions of teachers who could not be effectively reached in other ways, to help break the ice concerning computer literacy, and to reorient elementary teachers in fundamentals of arithmetic based on estimation and investigation rather than on computational accuracy.

New Linkages

Since the time of Adam Smith, education has been generally viewed as a public good, and consequently, as a public responsibility. But the current tax climate both in Washington and in the States suggests that this social compact may no longer be valid, that private interests may need to take over many parts of education that the public is no longer willing to support. Coincidentally, private enterprise has entered the educational sphere via computers, because computers are the products of private enterprise. The confluence of these two economic streams suggests that it is time to build new linkages between industry and education. Publishers and vendors who market their goods to education have a stake in the nature and quality of education, as do all the high technology industries that "consume" the products of education.

Establishing these linkages will not be easy. Industry will expect a return on its investment, and will ordinarily expect that education "put something on the table," as one participant put it. Public education, however, by both tradition and law, cannot easily perform in a manner that will provide a return to one company and not to its competitors; nor does education usually have the resources to put something on the table of equal value with private industry. Moreover, industry operates in a realm of private information and private contracts, using what academics usually call an "old boy" network to get the job done. Educators are accustomed to public information and public competition for ideas. For these reasons, industrial linkages with education have frequently been with individuals and not institutions: Teachers moonlighting or consulting with publishers or vendors can deal with private information without conflict because they are not representing their institutions. Direct industrial support for teachers is a far more complex matter, requiring of both sides what a recent Science editorial termed "large measures of good will, compromise, and recognition of mutual need."

Nevertheless, participants at this meeting seemed to agree that exploration of new patterns was essential and potentially beneficial. Instead of engaging in what one participant called the current pattern of "rape and pillage," high technology companies would benefit education more if they employed teachers part-time (in summer, and as consultants) on the condition that they remain in the classroom. Industry would gain the experience of practicing teachers and the manpower to carry out some of its development projects; teachers would gain in increased salary--a necessary incentive for anyone to remain in teaching these days--and in exposure to new ideas appropriate to the computer age; and the public would benefit from a structure that helps keep teachers in the classroom while reeducating them and increasing their salaries. Everyone seems to come out ahead in this scheme.

Another suggestion for industry-education linkage is for companies to set up private equivalents of the National Science Foundation: a structure of public announcements for competitive proposals in certain well-defined areas that would attract applications from teachers, school systems, colleges, and universities. This system also has the potential to benefit both sides. By encouraging numerous proposals, a corporation may discover some good ideas and opportunities that would not have come to its attention in the normal course of business; educational institutions that succeed in these proposals would have an opportunity to participate in enterprises that would invigorate faculty, motivate students, and perhaps entail economic benefits both to the institutions and to their employees. Even institutions whose proposals fail to be supported would benefit from the self-reflection required to prepare the proposals, and in some instances they may go ahead on their own.

Whether it comes from industry or government, venture capital for education-related computer projects is absolutely essential. We have barely scratched the surface of potential computer applications in mathematics education. Much more needs to be done to blend the expertise of mathematics teachers and computer specialists in imaginative and effective ways.

Support Structures

Concern for the needs of teachers led to several suggestions for support structures that would make it reasonable for a teacher to get involved in computer methods without unreasonable frustrations. For example, someone opined that 95 percent of current software is simply "junk." Whether the percentage is this high or not, it certainly is high enough to make the search for suitable software very difficult. The incredible diversity of quality and sources for software suggests the need for a national catalog and reviewing service for software in mathematics education. Several organizations now provide some reviews, but no present structure is close to comprehensive nor do most reach the audience of mathematics teachers.

A collateral benefit of a reputable national reviewing service is that it would provide a base of experience for research in the effectiveness of various types of computer software. There is much controversy, for instance, concerning the value of computer games, and of computer-assisted instruction. Frequently only a few computer cognoscenti are aware of whatever studies have been done. To make computers effective in mathematics education, it is important to link the community of computer professionals with the community of mathematics educators in some type of new professional alliance. Certainly existing professional organizations (such as NCTM and MAA) must reexamine their linkages with the computer community to see if they can (or should) broaden their roles to include full support for computer-based mathematics education.

A second suggestion for support structures to assist teachers in using computers concerns hardware more than software: Since public schools frequently will not have the maintenance personnel required for minor computer repairs or even installation of new equipment, it might be very useful if schools could link up with nearby colleges and universities to share the services of individuals who have this expertise--to avoid paying industry wages for onsite maintenance. Plugging together computer components is not as straightforward as it may seem to the novice. All too often school systems must rely for these services on individuals who do not have a commitment to public education, and who are not accustomed to working within the "make-do" budget of most districts. School districts need access to competent, committed computer personnel to provide support for all teachers who use the equipment.

Projections and Visions

By 1990, the microcomputer generation will be grown up. Kids who started learning computing in junior high will be finishing college and entering the work force, totally free of the computer phobias that afflict their elders. That's when the computer revolution will be over.

The key issue facing our society now is how we guide today's youth toward that postrevolution age. If public education falters--because of declining tax revenues--then private industry will surely step in to fill at least part of the void. The issue then becomes one of social policy: If computer education should emerge more in the private than in the public sector, how can it be prevented from becoming a privilege rather than a right? What steps should we take now to assure that by 1990 all high school graduates have adequate exposure to computers (not just rudimentary computer literacy) to function in a postrevolutionary computer society? The consensus of the Chicago meeting is that the task for the present moment is to develop public awareness of the issues and to provide teachers with the training and resources to get the job done.

NSF-NIE REGIONAL MEETING IN NEWTON (BOSTON), MASSACHUSETTS

July 7-9, 1981
Edith H. Luchins

ANNOTATED AGENDA

Tuesday, July 7

7:30-7:35 p.m.: Welcoming remarks
Janet Whitla, Education Development Center

Dr. Whitla, president of the host organization, stressed the need for this kind of forum, bringing together researchers, practitioners, teachers, and disseminators of knowledge for imaginative thinking about the future of mathematics education. She was particularly concerned about the shortage of women for teaching high school mathematics; the most talented and best prepared are being diverted to industry, where the rewards are substantially higher and the frustrations far less. In what ways, she asked, can information technology be used to better prepare women who do enter mathematics teaching and to improve the teaching possibility in the classroom?

7:35-7:45 p.m.: Introductory remarks
Edward Esty, National Institute of Education

After introducing Gloria Gilmer of NIE and Dorothy Deringer of the National Science Foundation, Dr. Esty spoke briefly about the general plan of the NSF-NIE joint program on the improvement of mathematics education through information technology. Issues pertaining to such improvement were being discussed in four regional meetings, each with its own theme, which were organized around the Agenda for Action of the National Council of Teachers of Mathematics (NCTM). This meeting, the third in the series, would focus on how computers could or should be used in the next decade in mathematics education, with its specific concerns the concomitant changes in teacher education and in the relationships among educators, researchers, publishers, and others. The kinds of questions the participants might think about were illustrated in the Esty-Gilmer-Deringer "three page" paper.

7:45-8:00 p.m.: Precollege Mathematics Education Using Computers--A Slide Show
Dorothy Deringer, National Science Foundation

The agenda had been described as a compromise between show-and-tell and talk. The next item on the agenda was a lively combination of both. Dorothy Deringer noted that the meeting did not have to reach consensus (unlike some meetings where consensus was the goal). The aim here was to get different ideas and guidelines for future development. She asked us to think in terms of a timeline, noting that it is difficult but important to have an idea of when something will happen, and a "laundry list" of priority items.

In planning for the future it is helpful to know what has happened or is happening at present. Therefore Dr. Deringer showed a dramatic slide show on NSF-NIE projects dealing with the improvement of precollege mathematics education using technology. (As is customary, no slides were included from projects whose personnel were attending the meeting.) Dr. Deringer raised such questions as these: What topics in mathematics attract computers? What can be done to raise computer literacy? Can young children learn mathematics using computers? Will interactive graphics improve mathematics learning? Will it do so for women, for minority group members, for reentry adults?

Describing the types of microcomputers used in the projects (Apples II predominate) and the languages used (mainly Pascal and BASIC), Dr. Deringer emphasized that the system requested by an investigator was almost always accepted. She pointed out that two-thirds use color graphics but few say why they are using color.

8:00–8:30 p.m.: Presentation on the challenge from the international community
Seymour Papert, Massachusetts Institute of Technology

Dr. Papert, author of Mindstorms, said that he had torn himself away from working on a new book, The Computer Manifesto, which deals with learning as a political process. With the computer, the exporting of knowledge need not be culturally destructive. People in a country like North Africa do not have to take our knowledge as it is, but can adapt it to their ways of thinking about the world and relating to others.

Children also can adapt the computer to fit their personality types and needs. There are children who are attracted by the flashing lights and action, the dynamic aspects of the computer. Others are more obsessional and want things to be perfect and precise. If he didn't have to submit the title to Congress, Dr. Papert quipped, he'd call it "Mathematics for Hysterics and Obsessionists."

Mathematics can be infinitely varied and modified. The computer permits variations in approach which were not feasible until now.

Dr. Papert described a school in Dallas, Texas, with some 200 children in grades 1 through 4, which has 60 microcomputers available. There is evidence there of both hard and soft mastery of the computer. Hard mastery involves seeing and doing something exactly. Soft mastery means doing something, then making a change and interacting; Dr. Papert compares it to getting people to do things. But there need be no differences in the outcome, in terms of getting to know the computer.

The goals in most schools is a computer per classroom. This is not continuous with the computer future which requires a computer per child. Imagine if there were one pencil per classroom!

Isn't it too expensive to give each child a computer? Dr. Papert holds that there are political and not economic obstacles to this goal. In New York City, it costs about $40,000 in tax money to educate a child from kindergarten to twelfth grade. Give each one a computer and even if you have to replace it every 4 years or so, the cost per child would be only about $2,000. This small fraction of the present cost could be saved by having somewhat fewer teachers. The spread of computers in education has been hindered not only by special interest groups but by thinking of computers as expensive and scarce resources.

Computers can produce radical changes in education in the next 10 years in developing countries. Some projects in the planning stage involve interaction with Jean Servan-Schreiber, the journalist famous for the thesis of World Challenge: Developing countries should not try to catch up with industrialized countries, but should go to the Computer Future. Several school projects are underway in Africa in which Dr. Papert is involved.

He concluded his talk by asking that in evaluating an educational approach or product, the "continuity principle" be used: Is it continuous with what we will have in the future?

Wednesday, July 8

9:00-9:45 a.m.: Demonstration on using computers to force awareness
Caleb Gattegno, Educational Solutions, Inc.

Dr. Gattegno has been studying the role of awareness in learning for 40 years. His concerns are: (1) What can children do by themselves? (2) All things that they can't invent, they have to be given. (3) To force awareness, provide challenges which are clear enough so the child knows what to do.

The same awareness is appealed to as in learning to speak, which is one of our greatest achievements. Since there is much of language in mathematics and conversely, it is advisable to use language as an entry to mathematics. To demonstrate this, Dr. Gattegno showed a computer program on numeration which synthesizes sound and light, the spoken and the visual numeral. With it, he can teach a young child (4 to 6 years) in about 20 minutes how to read six-digit numbers. Moreover, the program can be used to get numeration in any base.

9:45-10:15 a.m.: Demonstration of tools for training spatial visualization
Edwin Rogers, Rensselaer Polytechnic Institute (RPI)

Dr. Rogers reviewed the structure and goals of the project being undertaken at RPI with co-investigators Edith Luchins and James Voytuk. The focus was on hardware and software design decisions made to support microcomputer-assisted spatial visualization training sessions. These will take place in two high schools, one public and one private. Tutorial structures and graphics software which are being designed and implemented in the project were reviewed. Some of the latter were demonstrated, including the implementation of "hidden figure discovery exercises." The project, now midstream, will complete software and courseware development this fall. A presentation is planned for NCTM's Toronto meeting in April 1982.

10:30-11:15 a.m.: Demonstration of materials on estimation
Phyllis Klein, Consultant

Ms. Klein discussed the importance of the computer for estimation skills. These neglected skills call for frequent exposure to problems in different contexts. The microcomputer is suited to provide a variety of problems, and, with its random number function, to generate as many practice problems as desired.

Ms. Klein turned the participants loose to work in small groups at the computers. They welcomed this hands-on opportunity with the programs which included guessing the numbers of dots or elephants in a random array and estimating which product of two integers was larger.

11:15 a.m.-12 noon: Group discussion on future directions

As leaders in the computer revolution, what is our responsibility? How is information to be shared with teachers, administrators, people in higher education, publishers, vendors, and others? How do we get them to work together? Some of the suggested answers are described in the section on conference issues.

12:00-1:30 p.m.: Panel on publishing in the age of microelectronics

Irwin Harris of McGraw-Hill Book Company described its various divisions. (One of them, the Webster Division, had started in that very meeting room, Adeline Naiman pointed out.) For 2½ years, McGraw-Hill has been investigating going into electronic education. Publishers are confronted with the apparent reluctance of teachers to embrace computers. Nonetheless, McGraw-Hill has made the decision to enter the market in fall and winter 1982 with a computer literacy program aimed at bringing about awareness (an ability to function comfortably in a computer society), literacy (which requires hands-on experience with an unstructured language such as BASIC), and, finally, fluency (ability to use the computer efficiently as well as a structured language such as Pascal). Programs are aimed at junior and senior high school students. There are also plans for computer management instruction (CMI) and for computer-assisted instruction (CAI).

Since it now has few in-house editors, McGraw-Hill is looking to outsiders for ideas. Dr. Harris distributed a list of questions it asks sponsoring editors to consider.

How does someone with course material send a publisher a "proposal"? It is best to telephone and find a specific person to approach, who can then contact you if more information is necessary.

What does a publisher look for in submitted material? Is it marketable? Is a customer base ready? Does the publisher have a market unit that can do it? It may take 6 months to pull together such information.

Sylvia Clark of Ginn & Company was pleased to see teachers at the meeting. She had been fearful that researchers talked only to each other. Ginn has computer programs in reading and writing, as well as preliminary mathematics CAI, CMI, and game simulation programs. Xerox, which owns Ginn, has put out "Small Talk" and "Buggy." Demonstrations were later given of the latter.

Dr. Deringer noted that NSF is interested in getting the materials it supported as prototypes into the market. Circular No. 123 describes how to inform NSF if you plan to submit material to a publisher. The representatives indicated that publishers would probably be interested in early involvement. They need input from software and courseware developers, from teachers, and from students.

1:30-2:00 p.m.: Demonstration of instructional games for grades 1-4
William Kraus, Wittenberg University

Dr. Kraus demonstrated mathematical games that he has developed. Showing a colorful scene complete with golf ball, water, and sand, the computer asks what angle the student wants to play and how many units long the drive is to be. This Golf Game provides estimation skills for angle measurement and distance. In the Jar Game, which shows random and changing arrays of small green and gold shapes, the idea is to pick the jar with more gold shapes; it is a probability readiness game. Other games illustrated were Fish, a drill and practice game, and Pattern, a spatial relation game. The participants eagerly tried the games themselves.

2:00-2:15 p.m.: Demonstration of "Buggy"
Sylvia Clark, Ginn & Company

Dr. Clark demonstrated a "debugging" program intended for teachers of middle grades. Based on actual arithmetical mistakes, it shows a sequence of arithmetical problems in which the same error is repeatedly made, e.g., failure to carry. The goal is to discover the underlying systematic error and use it in subsequent problems in the sequence.

2:15-3:00 p.m.: Panel on elementary mathematics teaching in the age of microelectronics

The panel discussion was combined with the small group discussions later in the afternoon. In addition, comments on elementary mathematics teaching were made throughout the conference by the panelists: Phyllis Klein, consultant; Jane Manzelli of Watertown Public Schools; Adeline Naiman of Technical Education Research Centers; Susan Jo Russell of Cambridge Public Schools; and Catherine Tobin, Chairman of the NCTM Technology Advisory Committee.

Among the questions raised by the panelists were the following: Do teachers view computers as important, as aids, as hindrances? Are they reluctant or eager to use them? How do they find out what is available? How do they judge the quality of software and discriminate between good and bad material? It was noted that at present teachers do not have the time and resources to do the work of developing software and courseware and integrating them into the curriculum. Nevertheless, elementary teachers may find that microcomputers are particularly helpful in content areas with which they are not especially familiar (e.g., probability, geometry) and as a substitute for manipulative materials in some contexts.

3:00-3:15 p.m.: LOGO demonstration

In response to many questions about LOGO after his speech, Seymour Papert had mentioned that his associate, Robert Lawler, would be attending the meeting. By popular request, Lawler gave an unscheduled and informal presentation of LOGO, with the help of his young daughters. He noted that even 3-year-olds were able to type in words and gain experience in the computer world. He also discussed the underlying cognitive science.

3:30-5:00 p.m.: Group discussions

Separate groups considered two areas of concern:

a. What kinds of changes will be needed in preservice and inservice teacher education and involvement over the next decade if the instructional potential of computers in mathematics education is to be realized?

b. In effecting curriculum change, what roles, responsibilities, and relationships could or should exist among publishers, teachers, people in higher education, and vendors (and others)?

Thursday, July 9

9:00-9:45 a.m.: Continuation of group discussions

9:45-10:30 a.m.: Demonstration of LOGO-based mathematics curriculum materials
Wallace Feurzeig, Bolt, Beranek & Newman

Dr. Feurzeig described LOGO-based mathematics curriculum materials which can run on various microcomputers. The assumption is that programed language can serve as a new framework for the entire mathematics curriculum. The idea is for students to begin to learn to program and for instructors to teach in terms of programs.

Dr. Feurzeig illustrated how a child can program the computer to laugh (LAFF) and to cry. In an easygoing way, the child is taught procedural embedding as well as more elaborate computational linguistics. The program provides a model of (naive) recursion.

10:30-10:45 a.m.: Presentation on evaluation of courseware
Catherine Tobin, NCTM Technology Advisory Committee

Dr. Tobin described NCTM's booklet "Guidelines for Evaluating Instructional Material." It provides forms which can be copied or modified, including a software evaluation checklist and a software documentation sheet. It also includes sample letters requesting information. It is important to let publishers know our interests. The booklet can be obtained from NCTM, 1906 Association Drive, Reston, Virginia 22091.

11:00 a.m.-12:15 p.m.: Reports from the discussion groups

Group A. Teacher Education: Goals, Techniques, and Strategies

Goals adopted by this group were as follows.

1985

1. Program for adult computer literacy developed.

2. Teacher education graduates required to be computer literate.

3. Material from inservice education widely available (kits, workshops).

4. Minimum of one computer per 100 students.

1988

1. All K-12 teachers required to be computer literate.

2. One computer per 20 students.

1990

1. One computer per 10 students.

Techniques and strategies suggested by group A covered primarily two areas.

1. Establish teacher support systems. Such systems might include hot-lines, training centers, and the placement of computers in schools for teachers' practice. In each school, a nucleus of two teachers and an administrator should be trained. The support system should include adequate maintenance to keep the machines running, teacher access to available software, and guidance in the selection of software.

2. Widen the circle of people and institutions involved. Efforts should be made to include teacher training institutions (for both preservice and in-service education) and to involve professional societies in leadership roles. Among these societies are the National Council of Teachers of Mathematics, the Mathematical Association of America, the American Mathematical Association of Two Year Colleges, various science teachers' groups, and the American Association for the Advancement of Science.

Specific strategies for accomplishing the goals listed above would include: (1) encouraging one or more of the professional associations to hold followup meetings of key decisionmakers; (2) encouraging the publication of articles and editorials in journals for administrators and in publications (e.g., newspapers) for more general audiences; and (3) establishing joint curriculum committees involving professional associations and teacher education institutions.

Group B. Relational Networks

The discussion here centered on the knowledge network relating educators, publishers, the Federal Government, and others with a stake in the computer revolution. The salient issues are described in the second part of the summary.

The timetable offered by this group was as follows.

1983

1. Many major publishers have CAI (mostly drill and practice).

1985

1. One-half of all K-12 students have access to computers.

2. One-half of all high schools have computer resource centers.

3. One-tenth to one-twelfth have access to computers at home (more drill and practice, but some problem-solving in computer games).

1986

1. A market exists for computers in schools.

2. There is a shortage of mathematics teachers.

1987

1. Publishers decide to make major changes in materials.

1990

1. There exist some basal series that are fundamentally different from today's materials.

CONFERENCE ISSUES

Microcomputers: Wave of the Future

Underlying the meeting was a premise so fundamental that it did not have to be made explicit, namely, that mathematics education would and should incorporate computers and, in particular, microcomputers (as contrasted, say, with timesharing on large computers). Testifying to this premise was the impressive array of microcomputers, rounded up for the participants by members of the EDC, and alined along the walls of the meeting room.

The variety of the microcomputers bespoke differences in preferences for computers and computer languages. Such variety posed problems for the producers, distributors, and users of computer software, problems which were touched on at the meeting. Who would decide which computers to buy, what language to use, what software to purchase? Would a company produce software for one kind of microcomputer? And who would make it available for other machines or in other languages? The problems enhanced the concerns of the participants that there be a network of computer users, producers, and distributors to help develop viable solutions.

Although it was not articulated, it seemed that computer equipment (in its present state) was not going to make it easy for educators trying to use software and courseware. Even in the hands of experts, there was some malfunctioning of the computers and related equipment. There was an Apple II with a recalcitrant key that sent a wrong signal, a television screen that showed unexpected colors, an Atari that would not cooperate with the software, a Pet that refused to get off its haunches, and a Texas Instrument 99-4 that had to be spanked occasionally. Moreover, at MIT a DEC-20, suffering from nervousness or a hardware problem, would not wake up and provide a LOGO demonstration needed for the meeting. Although the mishaps were quite readily taken in stride, they underscored the potentially serious problems of machinery malfunctioning in a live teaching environment. Cognizant of these and related problems, the participants called for appropriate preservice and inservice training of teachers; for more than one computer-oriented teacher at a school; for computer resource personnel; for a hotline for assistance; and for other readily available technical support with both hardware and software. They also recognized that some students (whether in third grade or in college) may be more computer-wise than the instructor, so that changes would be needed in customary student-teacher relationships.

Publish and Perish?

There was some disagreement concerning the roles of publishers. Opinions ranged over a wide gamut: from the view that publishers are essentially followers of market demands to the view that they can be innovative trailblazers; from the belief that private publishers would not touch even excellent material (unless they were sure it would sell), to the belief that they were useful sources to be explored for helping software have national impact; from the notion that small producers of software should be encouraged to broaden their scope for educational production and distribution, to the notion that only the large book publishers have the national distribution which is needed. Problems involved in copying discs were also noted. It was suggested that publishers should assume that copying would occur (and even encourage it) and provide additional services in courseware, manuals, or computer time.

Home Computer Power and School Computers

The meeting recognized that home computers were influencing the influx of computers into schools. The participants could not agree on whether, say, by 1985, one-tenth or one-half of homes would have access to computers. There were divergent views on whether the gap between the "haves" and the "have-nots" would widen or whether (and when) home computers would become so cheap that virtually every home would have one. Perhaps more important than numbers was the recognition that parents with home computers tend to be potent forces in the community and in the PTA's and that they would exert increasingly strong pressure on the schools to introduce and use computers. There were also differences in opinion as to how ready the community was for school computers. The pessimistic view held that parents are suspicious of change, teachers are not eager to change, and administrators are concerned about cost. The optimistic view was as follows: In general, citizens are concerned that schools are falling behind. In addition, school administrators and school boards may feel that technology will save them money and should be brought into the system. Teachers can be made enthusiastic about the potentialities of computers, and students excited about their use. What is needed is leadership to generate and harness intelligent enthusiasm for such computer use.

Federal Funds

There was general accord that the Federal Government must play a decisive role. It is important that Members of Congress, many of them first-time members, be helped to understand the nature and gravity of the problem. The National Science Foundation ought to give highest priority to rebuilding and invigorating science education; no other group can do this. The National Institute of Education, and the Department of Education, under any name, need to invest heavily in research and development for teacher education. Moreover, the Department of Defense--virtually the only agency with money--should not be neglected. It should be reminded of the need for trained technicians to operate sophisticated systems, and for people trained to refine and develop new technology. Private industry also needs such people and has a responsibility to see that they are educated for the future. In the words of Dorothy Deringer, children who grow up with microcomputers will develop the new technology.

Institutions and Professional Groups

It was noted that the military has a large school system serving its personnel. It provides an experimental opportunity to "computerize" a school system on a grand scale.

Institutions of learning as well as professional groups have key responsibilities in helping to make their members, and members of related organizations, aware of their responsibilities in improving science education through computers. Reference was made to universities, educational centers, research groups, and government agencies, as well as professional groups.

It was recognized that AAAS is equipped to serve as a catalyst for a network of key people in the drama. The AAAS has national scientific recognition and commands public attention and respect. Among the services it could perform, the following were cited.

1. Focusing on computers in education at the national meetings and in meetings of State affiliates. These meetings, as well as specially convened meetings, should involve influential people in the Federal Government, in State departments of education, in accrediting agencies, and in school administration, as well as other decisionmakers.

2. An editorial in Science and an expository article there on computers would be very helpful. Articles for other appropriate publications would be prepared.

3. AAAS could influence colleges and universities to provide leadership roles on the use of computers in science education.

4. It could gather information and cast it in a form appropriate for different audiences: principals, teachers, Federal agencies, Congress, State legislatures, and others. It could provide annual reports on computers in science education. It could also provide speakers on the issues.

5. AAAS might aim at getting consensus from educational and scientific societies on objectives, evaluations, and standards of software, courseware, and hardware.

6. AAAS would be in a position to foster long-term support for deserving research and development projects. This might help to avoid the failure of continuity which stems from political changes and a narrow annual budget viewpoint.

It was recommended that a followup conference be held by the AAAS to bring together key decisionmakers in determining the future of computers in mathematics education. This conference, and subsequent conferences, would provide forums where a widening circle of individuals and institutions would interact, not just leaders in mathematics education but administrators, labor and union representatives, teachers' groups from mathematics, physics, and other sciences, publishers and vendors, government agencies, State school boards and accrediting agencies, and others. The followup conference could be the first step in an establishment of a network of key players. It might lead to meetings where consensus is called for (cf. the reports by Gillespie and by Shain). It might result in the establishment of a center which could help formulate and carry out long-term plans. In any case, the first step is the recommended followup conference.

NSF-NIE REGIONAL MEETING IN WASHINGTON

July 15-17, 1981
Joyce Hakansson

ANNOTATED AGENDA

Wednesday, July 15
7:30-8:00 p.m.: Introductory remarks
NSF-NIE Staff Members

The participants at the conference were greeted and briefed by the NIE/NSF staff. Edward Esty, of NIE, in his introductory remarks, indicated that this was the last of four meetings in this series. The others at Berkeley, Chicago, and Boston had followed similar formats with slightly different focuses. The theme for this meeting was to be how mathematics education can and should change over the next 10 years.

8:00-8:30 p.m.: Demonstration of computer-based materials designed with teachers
Les Karlovitz, Georgia Institute of Technology

Dr. Karlovitz told about a project he had developed for five high schools. Two teachers from each school were participating in a project to produce computer programs to be used in high school mathematics classes. The project was to provide a model for ways to include the teacher in the creative process of developing materials for use in the classroom. Dr. Karlovitz felt that it was desirable for the teacher to be the creator, developer, and tester of materials--for both the benefits to the teacher and the potential for the development of materials. Some of the programs written by the teachers were demonstrated.

8:30-9:00 p.m.: Demonstration of computer graphics for graphing
Steven Seidel, Virginia Commonwealth University

Dr. Seidel demonstrated a program developed to provide graphic representations of graphing. The program, written in PASCAL, draws a parabola on the video screen. The student tries to duplicate the shape by guessing the coefficients. The program will graph the student's parabola, allowing the student to do a visual comparison between the two.

Thursday, July 16
9:15-9:35 a.m.: Presentation on computers in mathematics education
James Fey, University of Maryland

Dr. Fey discussed some of the basic ideas he would be exploring in his project. He has not yet produced any of the software he plans to use. He plans to put students in touch with problems to see how "little" they need to know to solve the problems. This information will be useful to help schools make changes in the mathematics curriculum that will reflect the needs of a "computer-rich" society.

9:35-10:20 a.m.: Demonstration of courseware for elementary school children
Joyce Hakansson, Children's Television Workshop

Dr. Hakansson demonstrated software developed for a children's computer gallery. The goal is to blend entertainment and education in computer programs so as to provide appropriate activities for children to do on a computer. Computer use and the practice of relevant skills by children ages 3 to 13 are the desired outcome of the project.

10:35-11:15 a.m.: Demonstration of the videodisc in education
Harvey Long, DiscoVision Associates

Dr. Long demonstrated some of the available videodiscs and discussed others. He sees the videodisc as an audiovisual device that will allow teachers to select and assemble materials and present them easily. There is a need to provide technology that teachers can understand and use--bridges must be built between reality and new technology. The videodisc tied to a computer will probably not be practical for individualized instruction, because it would demand too much equipment to be feasible. It is more realistic to think of group uses for the machine.

1:30-2:05 p.m.: Demonstration of a high school laboratory experience
John H. Staib, Drexel University

According to Dr. Staib, our culture has become permissive. This is carried into our schools and has allowed students to enter colleges before they are prepared to do the work. Students are not attentive in classes because the teacher must compete for their attention in a way that compares favorably with the professional actors they see on television. The textbooks used in schools are often dull, even though publishers have used a variety of methods to make the books and the subject matter more approachable. Students should be given an opportunity to explore a problem and decide which of a variety of solutions they want to use. There should not be emphasis placed on finding the one "right" answer.

The program at Drexel has been designed to devise a laboratory experience for a mathematics course. The computer is used to present a situation which contains a mathematical problem. The student solves the problem using a calculator to do the computation--the emphasis is on building problem-solving skills.

2:05-2:25 p.m.: Toward a Psychometric for Adventureland
Isaac Bejar, Educational Testing Service

Using a videodisc connected to a computer, Dr. Bejar plans to prepare some mathematical tasks for young children that will integrate learning and assessment. A psychometric approach will be employed in the program--by keeping track of student errors, the program can tailor the instruction to meet the student's learning needs.

2:25-2:50 p.m.: Demonstration of microcomputer materials
Edward J. Lias, Commodore Business Machines, Inc.

With a slide show and verbal presentation, Dr. Lias presented an overview of the expanded opportunities for information and knowledge to be delivered to individuals by the new technologies. Through the use of networking, teletext and videotext technologies, large data bases, both general and specific, and the microcomputer, the knowledge of the world will be accessible to any individual or business. Educational institutions will have to understand and use these technologies in order to remain alive and relevant. Commodore Business Machines, Inc. is manufacturing a varied line of microcomputers appropriate for use in homes, schools, and business as independent devices or to serve as links to other information sources or individuals.

3:00-3:30 p.m.: Demonstration of the microcomputer applied to the science curriculum
Carl Davis, North Carolina School of Science and Mathematics

This summer, computer workshops for teachers were held at the North Carolina School of Science and Mathematics. The workshops were 2 weeks in length and two sessions were held to provide computer programing skills to 150 teachers. The summer workshops were successful as measured by the enthusiasm of both faculty and attending teachers and the skills acquired by the teachers. A continuation workshop was requested by the attending teachers and is being planned for next summer. Some of the things Dr. Davis mentioned he learned from the teachers are:

1. A demonstration disc to be used by the teacher should accompany school-based computer materials.

2. There is a real need for computer-based courseware in rural schools, especially where there are not enough students or funds to support an "expert" in the subject on the faculty.

3. Microcomputers are usually found in the schools in quantities of one or two. As of now, they are not readily available in the North Carolina schools.

4. Parents and parent groups are purchasing computers for schools.

In the fall, each mathematics class will cover a unit on numerical treatment of experimental data. The unit will include a conceptual treatment of least squares approximation (linear, quadratic, exponential), simulations of experimental error, and graphical techniques such as semi-log and log-log. The graphics capability of the microcomputer will be fundamental to the treatment.

Arthur Jones, Atlanta University

Atlanta University personnel have been using minicomputers, and now they have added microcomputers. The micros are transportable, which is important, as there is a scarcity of computing resources. Dr. Jones noted that the chemistry department makes extensive use of computers due to the enthusiasm of one faculty member. The social sciences at the university provide most of the computer users as the result of a program to upgrade the quantitative approaches in these disciplines.

Thomas Rowan, Montgomery County (Maryland) Public Schools

Dr. Rowan has been working on a computer literacy project aimed at the K-8 level. The goal of the project is to find and create computer applications that are useful in teaching mathematics, science, social studies, and language arts. The students should develop a sense of control over computers and information. The computer is used as a problem-solving aid. The program is using the "infusion approach," introducing the computer to be used in concert with other teaching methods in the classroom. The computer is not viewed as a replacement for existing curriculum. In order to introduce computers into the classroom effectively, teacher training must be provided.

James Friedie, Franklin Research Center

A group of volunteers has established teacher training centers in and around the Washington, D.C., area. People who own microcomputers make them available to educators who wish to learn how to use them. The project does not have any costs associated with it, as all the participants are volunteers. It was suggested that this model would work well in many other communities.

3:30-5:00 p.m.: Group discussions

The group was asked to divide into two discussion groups, to consider these questions:

a. In effecting curricular change, what roles, responsibilities, and relationships could or should exist among teachers, publishers, vendors, and people in higher education and in government?

b. What exciting and innovative changes (both in content and in presentation) are now possible in ~~the~~ mathematics curriculum, and how can these changes be realized in the schools?

Group A raised the question of how industry could help the government in its role of assisting the introduction of technology into the educational process. Edward Lias pointed out that it is difficult for hardware manufacturers to know where and how to place the limited resources they have for grants to educational institutions. Education represents a very small percentage of Commodore's market.

The lack of good educational software was cited as a severe impediment to the introduction of computers into the classroom. The lack of industrywide standards for language and graphics greatly aggravates the software situation.

Some private schools are being created to provide instruction in the use of computers for children. Parents are joining their children to learn about computers.

Friday, July 17

9:00-9:20 a.m.: Welcoming remarks
Milton Goldberg, National Institute of Education

The National Institute of Education has been holding meetings with the leaders of industry and superintendents of school districts. Both groups expressed interest and concern about the role of technology in education and expressed the view that government should play an important part in determining and facilitating that role. The role of government should be in the areas of research, development, and dissemination of information. The Federal Government should participate in joint development of educational technology sponsored by government, foundations, and business. The Federal Government must help in the production of educational software--helping to create markets and support for developers.

Robert Watson, National Science Foundation

The National Science Foundation has been actively supporting technology in education. Some of the major projects funded by the NSF include the development of BASIC, PLATO, LOGO, and MUMATH. There is a need for the development of knowledge networks for the sharing of information with individuals and institutions.

9:20-9:40 a.m.: Precollege Mathematics Education Using Computers: A Slide Show
Dorothy Deringer, National Science Foundation

Dr. Deringer presented a slide show illustrating the NSF/NIE funded projects not represented at this meeting.

9:40-10:15 a.m.: Demonstration of Courseware for graphing
Sharon Dugdale, University of Illinois

Dr. Dugdale demonstrated programs developed to run on the color Micro-PLATO system. The programs provide a rich and highly motivating environment for students to explore. The computer, when used in this way, provides students access to ideas and stimulates cooperative interaction among them.

10:15-10:35 a.m.: Presentation on mathematics education in the future
Max Sobel, National Council of Teachers of Mathematics

Dr. Sobel indicated that we currently have many dreams and many "pipe dreams" for the future of education in a computerized society. The importance of the teacher in the educational process cannot be overlooked. To be effective, the educator must be viewed and treated as a valuable professional with the status and salary commensurate with this position. In order to create innovative uses of computers in education, we must have teacher training. Currently, most teachers are not literate about computers.

10:50 a.m.-12 noon: Discussion of the role of the Federal Government in computers and education

This open discussion yielded several facts and concerns.

1. We should be learning from the experiences of other countries and other cultures.

2. Curriculum development should be done at the Federal level. We need to generate dialogs to initiate changes in the system.

3. Publishers have a profit motive which may or may not be consistent with innovative changes.

4. The mathematics taught to students must be appropriate for the changes in society and for the needs of the students.

5. The Federal Government does not have a defined role in public education.

6. Legislated programs can cause a backlash--e.g., the legislated programs for the disabled.

7. Industry is currently spending $50 billion each year on staff training and development.

8. Should the Federal Government have a role in examining electronic, educational toys produced for distribution to homes?

1:30-3:30 p.m.: Selected presentations
Gene Klotz, Swarthmore College

It is difficult to foresee the future in the development of new technology. Microcomputers have been available for only 5 years now and things are developing rapidly. Our current hardware is acceptable; we need better software. A California study shows that of currently available software, only 3-4 percent is acceptable to teachers. There is a real need to educate people about computers. We need to look for national curriculum efforts to incorporate new technologies into the classroom. Technology is here and cannot be avoided.

Demonstration of courseware for young children
Audrey Champagne, Learning Research and Development Center

Dr. Champagne's work has focused on the errors children make in arithmetic. She has found that the errors children make in doing subtraction are systematic. Her software provides children with physical representations for number symbols. The computer takes the place of manipulatives and has the advantage of being intrinsically motivating and allowing older children a chance to practice these skills without feeling embarrassed.

Demonstration of microcomputers in junior high school mathematics
Mary Grace Kantowski, University of Florida

Dr. Kantowski has been teaching students problem-solving processes through computer programing. Students, through their work on the computer, are able to understand complex mathematical relationships and are able to explore a variety of problem-solving approaches. The program has provided an opportunity for students to use the computer as a "tutee" with the student as the "tutor."

CONFERENCE ISSUES

The Washington meeting, taking place as it did in the Nation's Capital, focused on the role of the Federal Government in the process of improving mathematics education. Participants represented a variety of interests including university educators, teachers, hardware and software producers, government officials, and professional organizations.

An underlying concern expressed in a variety of ways was that the cutbacks in the Federal budget for the funding of educational projects would leave a void both in research and development and in the leadership needed to accomplish change and improvement in existing systems. The hope was that the existing need for strong leadership for change and continued research and development in science and mathematics education would be viewed as a national goal and the coalition of the institutions represented by the members of the group would emerge to support these efforts.

There was a sense of agreement among the participants on two basic issues:

1. The content of mathematics curriculum and the methods used in mathematics education need change.

2. Computer technology must be included and integrated into this change.

Following are the major topics that were addressed as problem areas. As in the other meetings preceding this one, the problems greatly outweighed the proposed solutions.

Teacher Training

In order to use computers in their classrooms, teachers need training. They need to get over their fears of the technology, both as a mechanical device and as a perceived threat to their jobs and positions in the classroom. They have to learn how to use the machine even if that knowledge is at the most basic level of how to assemble the equipment and turn it on and off. They must become either consumers or creators of curriculum and software. This need for information and experience has been successfully addressed by at least three of the projects represented at this meeting. At the North Carolina School of Science and Mathematics, groups of teachers are gaining computer skills at 2-week summer workshops. These teachers will now be able to use computers in their classrooms and will be able to assist other teachers in their schools.

At Georgia Institute of Technology, a more focused approach is being used. A few teachers are being given indepth computer training. These teachers are becoming very knowledgeable about the technology and have become creators of computer software for classroom use. These teachers are also serving as resources for their colleagues who need help getting started using computers.

The third project is a group of parent volunteers in the Washington, D.C., area who own personal computers. These people provide information and the opportunity for "hands-on experience" to teachers and administrators in the neighborhood schools.

Each project uses a different method to approach the question of teacher training. To reach the teachers of the country, all of these approaches and others will have to be used and multiplied thousands of times. There is no clear indication of who will do this, or how it will be funded.

Hardware

Although hardware was not the focus of any of the presentations or discussions at the meetings, it was clearly the topic of many of the informal conversations. A variety of machines were used for presentation and, in at least one instance, it was clear that the addition of high-resolution graphics and clear colors greatly enhance a program.

For the most part, the feeling expressed by the participants was that a great deal of improvement was needed in the quality of hardware available for use in the classroom. The machines are difficult for a novice adult to approach and use (the children have much less trouble). The available equipment is not powerful enough to do the most complex and involved activities software developers would like to present. Equipment has a propensity to break down--usually at the worst possible moment.

Manufacturers have not established industry standards for the hardware, making it difficult or impossible to exchange curriculum and software between machines. This segmented marketplace has created economic obstacles to curriculum and software developers and publishers.

The consensus at the meeting was that some of these problems were temporary, and that certainly lower costs, greater power, and more reliability would be characteristics of computers in the near future. There was also the feeling that educators cannot wait for improving machines but must make use of what is available now.

Software

A dominant theme of the meeting was the need for more and better educational software. The software demonstrations by NSF/NIE-funded projects were recognized as "exemplary models" that did not characterize the majority of available software. Most of the programs currently available for educational use do not meet even the most minimal standards. Either the content, the execution, or both are poor. Teachers are confused by the amount of untested, unevaluated, often unstable software that is distributed. Much of what has been produced and published is drill and practice--often nothing more than the transference of a workbook onto the video screen.

The scarcity of usable, appropriate educational programs is viewed as an impediment to the acceptance and use of computers in schools.

The question of where good software will come from was raised. There was concern that the educational publishers--the most likely producers--will be constrained by the economics of the marketplace from producing innovative products.

Curriculum

The need for a revised precollege mathematics curriculum was one of the often-stated themes of the meeting. It was felt that the new curriculum should place less emphasis on rote learning of computational facts and stress problem-solving skills. The curriculum must incorporate new technologies into the learning processes. It was often stated that the creation of this new curriculum must be viewed as a national effort, rather than a regional or local one. It was unclear as to how this project should proceed or who should lead it. Some suggestions were made that professional groups such as NCTM or MAA organize a national curriculum development effort. The question was raised as to whether, in fact, due to the perceived urgency of the issue, this was an area that the Federal Government should support. Although the questions surrounding curriculum development were not resolved, it was clearly a priority issue that will continue to be explored.

Government, Business, and Education

The location of this meeting in the Nation's Capital made it possible for many representatives of government to attend. Discussions centered on the role of government in effecting changes in the educational process. There was concern on the part of the meeting participants that current cutbacks in financial support for NSF and NIE would drastically reduce innovative developments in the areas of mathematics and science education.

There is a perceived need for a coordinated effort by government, business, and education to develop and promote the use of technology and education. Finding ways to combine resources and tackle the issues of teacher training, software and curriculum development, and hardware improvements in a coordinated, unified effort is clearly in the best self-interest of each of the groups involved. Of the three--government, business, and education--it is obvious that government should organize and coordinate such an effort.

It was suggested that as part of this leadership role, government should support research, development, and dissemination of information.

PARTICIPANTS AT THE NSF-NIE REGIONAL MEETING IN BERKELEY

Alfred Bork	Department of Physics, University of California at Irvine
Joseph Dasbach	American Association for the Advancement of Science
Dorothy Deringer	National Science Foundation
Judith Edwards	Northwest Regional Educational Laboratory
Edward Esty	National Institute of Education
William Finzer	Mathematics Department, San Francisco State University
Jane Gawronski	San Diego County Department of Education
Judith Hakes	All-Indian Pueblo Council
Wallace Judd	Apple Computer, Inc.
Daniel Kee	Department of Psychology, California State University at Fullerton
Arthur Kessner	Lawrence Hall of Science, University of California at Berkeley
Edward Landesman	Department of Mathematics, University of California at Santa Cruz
Brenda Laurel	Atari Computer, Inc.
Harold Miller	WICAT, Inc.
John Miller	Lawrence Hall of Science, University of California at Berkeley
David Moursund	Department of Computer Science, University of Oregon
Teri Perl	Advanced Learning Technology
Diane Resek	Mathematics Department, San Francisco State University
Ronald Saltinski	Dixie School District, San Rafael, California
Marc Swadener	School of Education, University of Colorado
Ramon Zamora	ComputerTown, USA!

PARTICIPANTS AT THE NSF-NIE REGIONAL MEETING IN CHICAGO

Joel Baumeyer	Mathematics Department, Christian Brothers College
Max Bell	Department of Education, University of Chicago
Ludwig Braun	College of Education, State University of New York at Stony Brook, SUNY/Stony Brook
John S. Camp	College of Education, Wayne State University
Joseph Dasbach	American Association for the Advancement of Science
Dorothy Deringer	National Science Foundation
Sharon Dugdale	Computer-Based Education Research Lab University of Illinois at Champaign
John Frey	Science Research Associates
Gloria F. Gilmer	National Institute of Education
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Herman Hughes	Computer Science Department, Michigan State University State University
Gerald Isaacs	Computer Science Department, Carroll College
James Johnson	CONDUIT, University of Iowa
Walter Kastenschmidt	Racine Unified School District, Racine, Wisconsin
Daniel Klassen	Educational Research & Academic Computing, St. Olaf College
Dee Lee	Scott-Foresman & Company
Barbara Martin	Waterford School District, Pontiac, Michigan
Bodie Marx	Milliken Publishing Company
Sidney D. Nolte	Texas Instruments, Inc.
Lynn Steen	Mathematics Department, St. Olaf College
Dorothy Strong	Chicago Board of Education

PARTICIPANTS AT THE NSF-NIE REGIONAL MEETING IN NEWTON

Sylvia Clark	Ginn and Company
Dorothy Deringer	National Science Foundation
Edward Esty	National Institute of Education
Wallace Feurzeig	Bolt, Beranek and Newman
Ross Finney	Education Development Center
Caleb Gattegno	Educational Solutions, Inc.
Gloria F. Gilmer	National Institute of Education
Irwin Harris	McGraw-Hill Book Company
Phylis Klein	Consultant, Watertown, Massachusetts
William H. Kraus	Department of Mathematics, Wittenberg University
Edith H. Luchins	Mathematical Sciences Department Rensselaer Polytechnic Institute
Jane Manzelli	The Russel Lowell School, Watertown, Massachusetts
Adeline Naiman	Technical Education Research Centers
Robert Oliver	Education Development Center
Seymour Papert	Division for Study and Research in Education, Massachusetts Institute of Technology
Edwina Rissland	Computer Science Department, University of Massachusetts
Edwin Rogers	Mathematical Science Department, Rensselaer Polytechnic Institute
Susan Jo Russell	Martin Luther King School, Cambridge, Massachusetts
F. James Rutherford	American Association for the Advancement of Science
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PARTICIPANTS AT THE NSF-NIE REGIONAL MEETING IN WASHINGTON, D.C.

Richard Anderson	Mathematical Association of America, Washington, D.C.
Isaac I. Bejar	Educational Testing Service
Joseph Caravella	National Council of Teachers of Mathematics
Audrey Champagne	Learning Research and Development Center
Joseph Dasbach	American Association for the Advancement of Science
Carl S. Davis	North Carolina School of Science and Mathematics
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Edward Esty	National Institute of Education
James Fey	College of Education, University of Maryland
James Friedie	Franklin Research Center
Gloria Gilmer	National Institute of Education
Joyce Hakansson	Children's Television Workshop
Arthur Jones	Department of Mathematics, Atlanta University
Mary Grace Kantowski	College of Education, University of Florida
Les A. Karlovitz	Mathematics Department, Georgia Institute of Technology
Eugene Klotz	Department of Mathematics, Swarthmore College
Edward Lias	Commodore Business Machines, Inc.
Harvey Long	DiscoVision Associates
Wendy Pollack	Association of Science-Technology Centers
Thomas Rowan	Montgomery County Public Schools

PARTICIPANTS AT THE NSF-NIE REGIONAL MEETING IN WASHINGTON, D.C.

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