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ABSTRACT

Presented are four fact sheets relating to mathematics education topics and which were produced by the ERIC Clearinghouse for Science, Mathematics, and Environmental Education in 1981. Fact sheet topics are: (1) Females and Mathematics, (2) The Problem of Problem Solving, (3) Mathematics Teacher Supply and Demand, and (4) Microcomputers and Mathematics Instruction. (PB)

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ERIC/SMEAC Mathematics Education Fact Sheet Number 1

1981

Females and Mathematics

Attention in recent years has been directed toward the status of girls and women in relation to mathematics. How much mathematics to they take? How are they treated in mathematics courses? How do they perceive mathematics? Answers from research and other literature to these and other questions are summarized in this fact sheet. Additional information can be obtained from a variety of sources, many cited on a recent bibliography (Suydam and Kirschner, 1981). Two sources were of particular value in developing this summary. The first, prepared by Armstrong (1980), is an overview of the results of a two-year study conducted by the Education Commission of the States as part of the Women in Mathematics program The second is an ERIC/SMEAC publication, *Perspectives on Women and Mathematics*, edited by Jacobs (1978). ED 166 051

Female Participation in High School Mathematics

Only a small percentage of women has pursued a mathematics-related vocation, such as engineering Researchers have ascertained that most females are not prepared to enter such vocations because they lack the necessary mathematics background. Furthermore, it appears that in many instances girls have not chosen to enroll in advanced mathematics courses in high school, and have received insufficient encouragement or support to take such courses. The College Entrance Examination reported in 1978 that 63 percent of college-bound males had taken four or more years of high school mathematics, but only 43 percent of college-bound females had done so.

Results from both the Second Mathematics Assessment of the National Assessment of Educational Progress (Carpenter et al , 1981) and the Women in Mathematics survey (Armstrong, 1980) showed that male and female participation was similar for basic mathematics courses: general mathematics, algebra I, and geometry. The pattern changed for more advanced courses, however. In the NAEP assessment, statistically significant differences favored males in enrollment for trigonometry and for pre-calculus/calculus, while the Women in Mathematics survey reported significant differences favoring males in enrollment for algebra II and for probability/statistics Nonsignificant differences in enrollment for trigonometry and for pre-calculus/calculus also favored males

Another study similarly indicated that, beginning at about the level of algebra II and continuing beyond high school, girls increasingly decided not to study mathematics (Fennema, 1977)

Peer Influences on Female Participation

Females who chose to pursue advanced mathematics courses were found to receive less attention from their male peers (Luchins, 1976) and to feel uncomfortable with them in social situations (Fox, 1976) Since boys in grades 6 through 12 stereotype mathematics as a male discipline at a significantly higher level than do girls, it has been suggested that boys communicate this attitude to girls in various ways (Fennema, 1978). The Women in Mathematics survey found that in the twelfth grade peer influence had a significant correlation, albeit low, with participation in mathematics (Armstrong, 1980)

Differential Treatment by Teachers

Several researchers have found that teachers treat boys and girls differently in mathematics classes (Bean, 1976, Parsons et al., 1979). High-achieving boys received significantly more attention in high school mathematics classes than did other boys and girls, including high-achieving girls (Good et al., 1973). Furthermore, students tend to be influenced by what they believe the teacher thinks of them and their ability in mathematics Fennema and Sherman, 1976) There is also evidence that teachers expect sex-related differences in achievement (Fennema, 1978)

A study on teacher-student interaction in high school geometry classes reported differential treatment on such factors as offered responses, cognitive level of questions, sustenance and persistence, praise and criticism, individual help, and even conversation and joking (Becker, 1981) In general, the interaction patterns reinforced the sex-typing of mathematics as a male domain Becker hypothesized a three-step pattern.

(1) Teachers expect differences between male and female students.

(2) Teachers treat students differently on the basis of sex according to their differential expectations.

(3) Students respond differently in class consistent with teachers' and society's sex-role expectations

Stereotyping Mathematics as a Male Domain

Historically, mathematics has been regarded as a massculine discipline The results of the Women in Mathematics survey clearly indicated that mathematics is both a female and male domain Thirteen-year-old girls were found to be better at spatial visualization and computation than were boys, while their problems, solving skills were nearly equal. By grade 12, girls' abilities in spatial visualization and computation were comparable to boys', but boys excelled in problem solving (Armstrong, 1980). These findings seem to support Fennema's (1978) conclusion that no inherent factors exist which keep girls from learning mathematics at the same level as boys

The Women in Mathematics survey found that females who regard mathematics as a subject for both males and females tended to take more mathematics (Armstrong, 1980). In another study females in grades 6 through 12 denied the belief that mathematics is strictly for males (Fennema and Sherman, 1977).

Female Attitudes Towards Mathematics

In studies conducted 20 or more years ago, boys at the elementary school level seemed to prefer mathematics slightly more than did girls; that is, boys' attitudes were more favorable than girls' attitudes In more recent studies, however, no overall sex differences in preference or attitudes have been observed at the elementary school level (e.g., Ernest et al., 1975).

On subscale measures of attitudes, however, differences are found, particularly at the secondary school level Female students, to a lesser degree than males, viewed mathematics as personally useful (Fennema and Sherman, 1977). Research has also indicated that girls who regard mathematics as useful in their future are more likely to continue taking mathematics. For example, the Women in Mathematics survey found that twelfth-grade students who plan to continue their education beyond high school were more likely to take more advanced mathematics courses than were students with lower academic aspirations (Armstrong, 1980)

Anxiety and Confidence

As Armstrong (1980) stated, a student's attitude about mathematics reflects his or her enjoyment, con[illegible] and anxiety concerning the subject.

Low achievement in mathematics has bee[illegible] [illegible]ed with high anxiety, furthermore, low anxiety has [illegible] [illegible]related with a high degree of confidence. Fennem[illegible] [illegible]herman (1977) found that at each grade level 6 through 12, boys were significantly more confident in their mathematical ability than were girls, even though there were no significant sex differences in achievement

Parental Influences on Female Attitude and Achievement in Mathematics

Parents who use, enjoy, and have confidence in their ability to do mathematics have been shown to have a positive effect on students' attitudes toward the subject (Fox, 1976) Fox also found that the expectations of fathers influenced the mathematics achievement of girls. Several studies ascertained that parents, unfortunately, seem to have lower expectations for their daughters than for their sons (e g , Casserly, 1975, Levine, 1976)

Intervention Strategies

Increasing female participation is viewed as a key strategy for combating the factors that cause girls to avoid mathematics In addition, it is believed that sufficient female participation in high school mathematics courses will permit a woman to pursue a scientific or technical career on the basis of eoual opportunity

From the Women in Mathematics survey data, Armstrong (1980) identified three important variables that have an effect on mathematics participation.

- positive attitude toward mathematics
- perceived need for and usefulness of mathematics
- positive influences of significant other people (parents, teachers, counselors)

She suggested that intervention programs designed to increase participation should focus on " . instilling and sustaining the positive influences of these factors . ." (p. ix)

Furthermore, 14 action steps discussed by Burton (1978) have been helpful in increasing participation. The recommendations are practical and relatively easy to implement in the classroom For example, she suggested inviting guest speakers to mathematics classes and encouraging female students to encourage other female students

Fennema et al. (1981) concluded that intervention programs aimed at resolving the inequities in the study of high school mathematics can be effective For instance, the amount of mathematics female students planned to take was significantly increased in schools where the intervention program "Multiplying Options and Subtracting Bias" was in effect. Additional intervention programs are described in Jacobs (1978) (e g , by Afflack, Liff, and Tobias)

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ERIC/SMEAC Mathematics Education Fact Sheet Number 2

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The Problem of Problem Solving

Why has so much been written about mathematical problem solving? Why has it been the object of more research than almost any other topic, especially at the elementary s... level? Obviously, the reasons lie with its importance in the school mathematics program — and with the difficulties it presents for both students and teachers. Recently, interest in problem solving has been sparked by several reports. This fact sheet will summarize these reports briefly and present some specific suggestions for teaching problem solving.

Defining problem solving

When you want something and do not immediately know what series of actions to perform to get it, you have a problem. Polya, one of the most widely cited writers on problem solving, offers the following definition:

> Solving a problem is finding the unknown means to a distinctly conceived end. If the end by its simple presence does not instantaneously suggest the means, if therefore, we have to search for the means, reflecting consciously how to attain the end, we have to solve a problem. To solve a problem is to find a way where no way is known off-hand, to find a way out of a difficulty, to find a way around an obstacle, to attain a desired end, that is not immediately attainable, by appropriate means. (Polya, in Krulik, 1980, p. 1)

Meiring (1980a) describes a mathematical problem as a situation involving an initial state and a goal state, with some blockage between the two. Furthermore, you must desire a solution, feel that it is within your ability, and believe that you can begin an attack on the problem.

Many of the so-called problems in textbooks are not problems at all for students, but merely exercises. Students already know what to do with many of them; thus "problems" requiring division are included at the end of the chapter on division. Students need many experiences with problems they do not know how to solve routinely.

The importance of problem solving

When the National Council of Supervisors of Mathematics developed a Position Paper on Basic Mathematical Skills in 1977, problem solving headed the list. Why? It was noted that "learning to solve problems is the principal reason for studying mathematics" (NCSM, 1977, p. 2)

In *An Agenda for Action: Recommendations for School Mathematics of the 1980s*, the National Council of Teachers of Mathematics proposed: "Problem solving must be the focus of school mathematics in the 1980s" (NCTM, 1980). Thus, it was suggested that:

- The mathematics curriculum should be organized around problem solving.
- The definition and language of problem solving in mathematics should be developed and expanded to include a broad range of strategies, processes, and modes of presentation that encompass the full potential of mathematical applications.
- Mathematics teachers should create classroom environments in which problem solving can flourish.
- Appropriate curricular materials to teach problem solving should be developed for all grade levels.
- Mathematics programs of the 1980s should involve students in problem solving by presenting applications at all grade levels.
- Researchers and funding agencies should give priority in the 1980s to investigations into the nature of problem solving and to effective ways to develop problem solvers. (pp 2-5)

Data from the Priorities in School Mathematics (PRISM) Project (NCTM, 1981) indicated that national samples of teachers, parents, and others agreed that problem solving should be given the highest priority for consideration in the 1980s.

Assessment evidence on problem solving

The second mathematics assessment of the National Assessment of Educational Progress (Carpenter et al, 1980a, 1980b, 1981) indicated that students aged 9, 13, and 17 scored very poorly on some types of problems. Average problem solving scores declined significantly between the first testing in 1973 and the second in 1978

Problem solving is often equated with solving verbal textbook problems, but this was not the type of problem that caused difficulty ... fact, students did "reasonably well" on one-step problems similar to those found in textbooks. When the corresponding computational skills had been attained, finding the solution to such problems presented little difficulty However, the majority of students at all age levels had difficulty with any problem requiring some analysis or thinking. Thus, "almost every problem that could not be solved by a routine application of a single arithmetic operation caused a great deal of difficulty" (Carpenter et al., 1980a, p. 8). Performance on multistep problems was lower than on one-step problems, but about the same as one more complex one-step problems. However, on several nonroutine problems unlike those generally found in textbooks and requiring the application of knowledge, skills, and understanding to somewhat unfamiliar situations, performance was generally poor.

Carpenter et al (1981) concluded:

> Students had difficulty with problems in many instances because they had not developed good strategies for solving those problems. For example, when faced with problems that contained extraneous data, students often attempted to incorporate all of the numbers given in the problem into finding their solution ... Students need to learn how to analyze problem situations through instruction that encourages them to think about problems and helps them to develop good problem-solving strategies. There is no magic formula ... (p 147)

Strategies for solving problems

To become a better problem solver, one must have experiences in solving problems. One must also have an understanding of procedures or strategies that are usually productive in solving problems. Strategies are general skills or abilities that can be learned, are useful in a variety of problems, may be used singly or in combinations to solve a single problem, and give the individual the tools with which to begin or continue productive work on a problem (Meiring, 1980a, p. 7).

Meiring lists 16 problem-solving strategies (and then goes on to develop each, with problems that can be solved with that strategy):

look for a pattern
construct a table
account for all possibilities (systematically)
act it out
make a model
guess and check
work backwards
make a drawing, figure, or graph
select appropriate notation
... the problem in your own words
...ntify wanted, given, and needed information
write an open sentence
identify a subgoal
solve a simpler (or similar) problem
change your point of view
check for hidden assumptions

Polya's (1945) four-step model is widely cited as a framework from which to develop problem-solving skills: understanding the problem, devising a plan, carrying out the plan, and looking back.

Research evidence on problem solving

Research has indicated some broad generalizations that appear to be true:

- Problem-solving strategies can be specifically taught, and when they are, they are used more and students achieve correct solutions more frequently.
- Learning strategies provides students with a repertoire from which to draw as they meet a wide variety of problems.
- There is no one optimal strategy for solving all problems.
- Students need to be faced with problems in which the approach is not apparent and encouraged to generate and test many alternative approaches.
- Some strategies are used more frequently than others, with various strategies used at different stages of the problem-solving process.
- Developmental level is related to a student's problem-solving achievement.
- Problem-solving skills are improved by incorporating them throughout the curriculum (Suydam, in press)

References to specific research include Driscoll (1980), Goldin and McClintock (1979), Sowder et al. (1979), Suydam in Krulik (1980) and Suydam and Weaver (1977).

Suggestions for teaching problem solving

A compilation of suggestions from research and other literature includes the following (Suydam, in press)

- Expose students to many, varied problems.
- Teach students a variety of problem-solving strategies, plus an overall plan for how to go about problem solving.
- Give students many opportunities to structure and analyze situations that really constitute problems and not just exercises.
- Encourage students to solve different problems with the same strategy and to apply different strategies to the same problem.
- Have students determine the question to be answered, select specific information necessary for solution, and choose the appropriate process Discuss why that process is appropriate emphasize what needs to be done and why it needs to be done rather than just obtaining an answer.
- Have students generalize and see similarities across problems, analyzing the structural features of a problem rather than focusing only on details
- Provide sufficient time for discussion, practice, and reflection on problems and problem-solving strategies
- Have students estimate answers and test the reasonableness of answers
- After they have reached a solution, encourage students to look back, to reconsider their own thinking and note how they might have solved the problem differently.

For further help, Meiring (1980a, b) presents ideas on how to incorporate problem solving into teaching: how to organize the curriculum, how to manage instructional time, how to evaluate problem solving, what teaching methods are most effective, how to use group work effectively, and how to make better use of the textbook in teaching problem solving.

The 1980 NCTM Yearbook (Krulik), focused on problem solving, contains a number of useful chapters on such topics as posing problems, pictorial languages in problem solving, the use of textbook problems, using the calculator to teach problem solving, and measuring problem-solving skills. An annotated bibliography includes references to teaching problem solving and to collections of problems

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ERIC/SMEAC Mathematics Education Fact Sheet Number 3 1982

Mathematics Teacher Supply and Demand

The popular press has announced for nearly ten years now that teaching is a poor career choice for young people. Declining birth rates and school enrollments have caused school planners to make major modifications in projections for needed teachers, classrooms, and buildings. The 1978 *Occupational Outlook Handbook* advises that the job situation for teachers is serious and concludes that "an increasing proportion of prospective teachers will have to consider alternatives to secondary school teaching" (p. 213). Popular literature from *Senior Scholastic* (1978) to *The Readers Digest* (1978) echo that a surplus of teachers makes teaching a very poor career choice.

The Special Case of Mathematics Teachers

At the same time the popular press was decrying a teacher surplus, a 1978 *Bulletin for Leaders* from the National Council of Teachers of Mathematics reported that a random survey of 200 mathematics supervisors indicated that "at the end of the 1977-78 school year almost 10 percent of the mathematics teaching positions were vacant." How is this possible with a surplus of teachers? The answer lies in looking at subject matter teachers in particular, rather than teachers in general. Data from *The State of Missouri Supply and Demand Survey* illustrate the special case of mathematics teachers. This survey measured demand for secondary teachers for each of the six years from 1973 through 1978, including positions available due to new course offerings or replacement of teachers leaving the profession. During the six-year period of the survey, an average of 1,244 positions was available for secondary teachers each year. For the same six year period, an average of 1,958 new teachers was produced each year by all the teacher training institutions in Missouri. This appears to be a surplus of 714 secondary teachers each year. However, when the data are broken down by subject area, the results appear to be quite different.

Table One

1973-1978 Teacher Supply and Demand Averages for Missouri

Teaching Major	Positions Available	Teachers Trained
English	285.7	378.0
Mathematics	245.5	216.8
Physical Education	206.8	613.3
Science	287.3	240.7
Social Studies	218.8	509.2

Source: *The State of Missouri Supply and Demand Survey*

Instead of a general surplus of secondary school teachers, these detailed data actually show a shortage of mathematics teachers and science teachers. These shortages are more than compensated for by large surpluses of teachers in the areas of physical education, social studies, and English. Whether one concludes that there is a surplus or shortage of teachers depends upon how well data reflect differences between secondary teaching fields. It is obvious that mathematics teachers (and science teachers) are special cases that do not conform to general discussions of "teacher surplus."

Enrollment Trends and Mathematics Demand

For many schools, enrollment peaked during the early 1970's. For example, in the state of Ohio enrollment in public schools reached 2,432,640 during the 1971-72 school year. By the 1980-1981 school year the number of public school pupils in Ohio had declined to 1,961,343. By the 1990-1991 school year enrollment is projected to drop to 1,726,743. However, there has been a slight increase in the birth rate since 1977. Because of this increase, enrollment in grades K-8 by 1990-1991 is anticipated to be only 5.8 percent less than in 1980-1981. Enrollment in grades 9-12, however, is expected to be down by approximately 22.8 percent for the same ten-year period (Ohio Teacher Supply and Demand, 1981).

Will these declines in enrollment offset any future shortages of mathematics teachers? At least two factors must be considered in answering this question: enrollment trends in mathematics teacher education programs and demand for mathematics courses by secondary school students. The latter factor, in particular, seems to have been largely ignored by many of the current surveys and analyses. There is some evidence that both students and their parents are beginning to realize the importance of mathematics in an increasing number of careers. When a student limits his or her study to one or two years of high school mathematics, he or she is foreclosing on many career options in both college and vocational schools. As mathematics becomes required in more and more twenty-first century professions we should expect more and more demand for mathematics courses from secondary school students. In one suburban Chicago high school school enrollment dropped from 55,305 students in 1978 to 51,017 students in 1980, a decline of 7.8 percent. At the same time, enrollment in mathematics courses dropped from 34,704 to 33,573, a decline of only 3.3 percent (Cummins, 1981). The National Council of Teachers of Mathematics has called for the requirement of at least three years of mathematics in grades 9-12 (NCTM, 1980). Some of this additional work may well be devoted to computers and computer literacy as the revolution in microcomputers touches almost every aspect of the work world. Thus it seems reasonable to assume that enrollment in mathematics courses in secondary schools will *not* decline as rapidly as general secondary school enrollments. Indeed, as mathematics offerings are expanded with courses in computer literacy and computer programming, the total number of students enrolled in all secondary school mathematics courses may not decline at all.

Enrollment Trends in Mathematics Teacher Education Programs

The decline in students preparing to become mathematics teachers has far outstripped decline in enrollments in secondary schools.

What are the reasons for this precipitious drop in mathematics teacher preparation? Certainly all the negative publicity about a surplus of teachers and a shortage of teaching jobs has discouraged may young people from teacher education programs. But Clyde A. Paul suggests three other reasons for declining enrollment in mathematics teacher preparation programs (1979). More females are bypassing the traditional occupation of teaching in order to train for positions formerly dominated by males. Students from the middle and lower-economic classes are realizing that blue-collar apprenticeship programs provide quicker and more substantial financial rewards than does a teacher-training program. And finally, more students are selecting college training that will provide financial rewards rather than personal satisfaction. Indeed, William S. Graybeal of the National Education Association points out that the average beginning salary offered by private industry to bachelor's degree graduates in mathematics-statistics in June 1978 was higher than the average 1978-1979 salary paid to *all* public school teachers in each of twenty-three states (1979). The decline in enrollment in mathematics teacher education programs may prove to be impossible to reverse until we have improved the attractiveness of careers in mathematics teaching.

Supply Variations by States

Because of space limitations in this fact sheet we have been selective in citing data to support premises. Just as one can sum data to support the idea of a surplus of teachers, or break data into categories to argue a shortage of teachers, so can data be drawn from different geographical areas or special communities to support different conclusions. Indeed, it is particularly dangerous to overgeneralize about mathematics teacher supply and demand. Situations vary greatly from state to state and from community to community. Some schools face declining enrollments because of declining populations; others are expanding because of economic and population shifts. Some school systems are retraining teachers that are surplus in other areas to become mathematics teachers. Others find their needs for mathematics teachers are modified by the need to close school buildings and reorganize school districts. The following table of estimated supply of secondary mathematics teachers in 1980 gives some idea of this state-by-state variation.

Table Three

Estimated Supply of Secondary Mathematics Teachers by State, 1980

State	Supply	State	Supply
Alabama	*******	Missouri	critical shortage
Alaska	surplus	Montana	*******
Arizona	********	Nebraska	adequate
Arkansas	surplus	Nevada	surplus
California	slight surplus	New Hampshire	critical shortage
Colorado	adequate	New Jersey	adequate
Connecticut	shortage	New Mexico	shortage
Delaware	adequate	New York	critical shortage
District of Columbia	shortage	North Carolina	critical shortage
Florida	shortage	North Dakota	critical shortage
Georgia	surplus	Ohio	adequate
Hawaii	adequate	Oklahoma	critical shortage
Idaho	shortage	Oregon	critical shortage
Illinois	critical shortage	Pennsylvania	critical shortage
Indiana	critical shortage	Rhode Island	********
Iowa	critical shortage	South Carolina	critical shortage
Kansas	shortage	South Dakota	adequate
Kentucky	critical shortage	Tennessee	adequate
Louisiana	shortage	Texas	critical shortage
Maine	shortage	Utah	shortage
Maryland	shortage	Vermont	adequate
Mass.	surplus	Virginia	shortage
Michigan	shortage	Washington	adequate
Minnesota	********	West Virginia	critical shortage
Mississippi	********	Wisconsin	critical shortage

Source. State Department of Public Instruction, Iowa, as quoted in *Education Week*, November 23, 1981.

*** = no response

Because of variations from state to state and community to community, readers of this fact sheet who wish more detailed information on mathematics teacher supply and demand should contact their state department of education, local education units, and nearby colleges and universities. The local situation in Massachusetts, for example, is almost surely quite different from a local situation in, say, Indiana. The pooling and averaging of data on a nationwide basis may serve only to obscure variations and differences. Nevertheless, it is safe to conclude that a serious mathematics teacher shortage exists in much of the nation. Furthermore, available data and projections suggest that the problem will become more widespread in the foreseeable future.

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MICROCOMPUTERS AND MATHEMATICS INSTRUCTION

Computers have been used in some classrooms ever since the early 1960s, but it took the advent of the microcomputer to capture the imaginations of most educators. The notion of having at least one computer in every school suddenly became more than a dream. Up until the past few years, only 60 percent of the schools in this country had access to computers—and frequently that access was limited to administrative functions (Bukoski and Korotkin, 1976). Costs prohibited using computers extensively in instruction. Now the cost of a microcomputer seems attainable. As a recent editorial in the *Mathematics Teacher* notes,

> It is no longer a question of whether educators should be involved with computers. With the pervasiveness of computers, it is essential that students learn about them. For some individuals, this may simply be a matter of computer literacy, that is, familiarity with their capabilities and the kinds of functions they can perform. For others, the computer provides a vocational opportunity, and more detailed knowledge is required. (p. 588)

Now that we have the possibility or the capability of obtaining the hardware (the microcomputer, the television monitor, the disk drives, the printer), what will we do with it? What software (programs) do we need to use it effectively? How do we want to structure the curriculum to make maximum use of its power and capabilities?

A Matter of Record

A number of organizations have gone on record acknowledging the new role of computers in the curriculum. In 1977 the National Council of Supervisors of Mathematics issued a position statement on basic mathematical skills. One of the ten skill areas they listed was computer literacy, because

> It is important for all citizens to understand what computers can and cannot do. Students should be aware of the many uses of computers in society, such as their use in teaching/learning, financial transactions, and information storage and retrieval. The "mystique" surrounding computers is disturbing and can put persons with no understanding of computers at a disadvantage. The increasing use of computers by government, industry, and business demands an awareness of computer uses and limitations. (p. 2)

The following year, the National Council of Teachers of Mathematics endorsed a similar position statement:

> Every student should have first-hand experiences with both the capabilities and the limitations of computers through contemporary applications. Although the study of computers is intrinsically valuable, educators should also develop an awareness of the advantages of computers both in interdisciplinary problem solving and as an instructional aid.

This position was reinforced in the NCTM's *An Agenda for Action: Recommendations for School Mathematics of the 1980s*. One recommendation was that "Mathematics programs must take full advantage of the power of calculators and computers at all grade levels." They endorsed access throughout the school mathematics program; the integration of computers into the curriculum; the development of diverse, imaginative materials: a computer literacy course for everyone, including adults; the inclusion of computer literacy in teacher education programs and in certification standards; the design of computer courses for computer science work; coordinated home-school use of computers; the development of good software to promote problem solving; and the use of computers in other subject areas.

Advocates of using computers in schools are many and opponents are difficult to find. One illustration of this comes from the Priorities in School Mathematics (PRISM) Project, designed to assess preferences and priorities of both educators and lay persons before recommending curriculum development and change. Nearly 75 percent of the professional groups sampled and 80 percent of the lay people sampled believed that the use of computers and other technology should be increased during the 1980s; 78 percent indicated that the emphasis on computer literacy should be increased. Having computers or computer access for students was given strong support (95%) at the secondary school level and moderately strong support (77%) at the elementary school level. Strong support (84%) was also shown for having several microcomputers for each class.

Types of Uses

Computers can be used in the classroom in a variety of ways. Instructional computing involves the use of a computer as a tool for teaching and learning in any subject area, not just mathematics. Among the types of use are:

1. Computer-assisted instruction (CAI) — students interact with a computer through programs designed to provide practice or teach the student new content.
   - Drill and practice — programs designed to provide practice on knowledge and skills have been used extensively.
   - Tutorial—The computer is used to present an intro-

duction or review of ideas by attempting to simulate a good human tutor. Programs are often structured in a question-and-answer format. Diagnostic and prescriptive techniques are used, and the program can provide both remediation and enrichment or acceleration.

- Simulations — programs model experiences that are too complex, time-consuming, expensive, or dangerous to provide in reality.
- Games — programs are in competitive settings, for students to play, score, and win. Many of the games currently available have little or no educational value — teachers must be very wary.

2. Computer-managed instruction (CMI) — designed to assist the teacher in managing the instructional program.
   - Record management — programs store, analyze, and report data, such as records on student progress or grades, assignments, or alternative materials. The program can pinpoint student weaknesses and provide suggestions for individualized assignments, as well as producing randomized assignments.
   - Information storage and retrieval: information on content, methods, activities, research, and other background information is stored in the computer memory for access by teachers or, in some cases, students. One example of this type of use is provided by ERIC.
   - Materials generation — programs produce worksheets or tests, with alternate forms to meet individual needs, on monitor, paper, ditto masters, or overhead transparencies to use with students.
3. Programming and problem solving
   - Programming — students of all ages can use the computer to write (and execute) their own computer programs. Hatfield (1979) cites six reasons for having students program, citing what they can learn from it as well as examples of programming tasks.
   - Problem solving — when one can program, one can solve a problem using a computer. In addition, one can study problem-solving situations and strategies.

Computer Literacy/Awareness Objectives

Increasingly, a distinction is being made between "computer awareness" and "computer literacy." Computer awareness means becoming aware of the extent to which computers influence our lives. Computer literacy means being able to take an idea and express it in such a way that the computer can carry out your intent.

Johnson et al. (1980) searched curriculum materials, tests, and other reports to collect the various views on what is considered in teaching computer awareness or computer literacy. They grouped the objectives under six categories (omitting any on the history of computers):

1. Hardware: components and basic operation; how computers work and how to access them.
2. Programming and algorithms: communicating instructions and programming in BASIC or another language.
3. Software and data processing: what computers can do and how they do it.
4. Applications: uses in various fields; types of uses in general; advantages and limitations of computers.
5. Impact: on careers; on problems such as security, crime, privacy, etc.; their roles pervading society.
6. Affect: how students feel about and relate to computers.

This extended list of objectives can be used to "pick and choose," with selected activities or experiences allocated to various points not only in mathematics but also other portions of the school curriculum. The authors note that it may also be desirable to allocate a portion of some year to a course on computer awareness or literacy; it would include those objectives that require some reasonable time for study.

Luehrmann (1981) took exception to their list, detailing his arguments that four-fifths of the items involved points that could be studied without a computer being present — merely by listening to a teacher or reading a book. He believes that the computer literate individual must be able to perform on a computer. A response, defending the basic notion of a set of objectives that includes both knowing about and being able to perform, was advanced by Anderson et al. (1981). They stated:

> Indeed we would argue that most of what every ordinary citizen needs to know about computers will not be learned from learning how to program. (p. 688)

This argument may be of concern not only in schools with computers but also in the many schools which do not yet have computers available for all students but who would nevertheless like to have all students be computer literate.

Examples of computer literacy courses can be found in such journals as *The Computing Teacher* and the *Mathematics Teacher*. For example, one article presents the course developed by the Cupertino Union School District in California (1981). It provides objectives for a computer literacy curriculum stated in two ways. First, for those who want to include the objectives across the whole curriculum, they are structured under social studies, language arts, science, and mathematics. Second, they are regrouped for those who want to combine the objectives into a single junior high elective. In secondary school, students may go on to computer programming courses.

Curriculum Considerations for Mathematics Courses

Computers are a natural tool in both the learning and application of mathematics. (Of course, they can be used in many other curricular areas as well.) Johnson and Jongejan (1980) proposed some guidelines for the use of computers in mathematics courses:

1. Integration should be gradual.
2. A definite plan of attack is necessary:
   a. Determine a content area and desired student outcomes.
   b. List ways computer capabilities could help students understand the mathematical concepts involved.
   c. Collect and evaluate problems, laboratory exercises, and existing computer software related to these concepts.
   d. Develop an appropriate instructional strategy to capitalize on computer capabilities.
   e. Develop additional software needed.
   f. Implement — then evaluate and revise.
3. Compensation should be given to educators attempting to integrate the computer.
4. Encouragement and support should be given to research on computer uses.
5. Plans should be made for developing teacher competence in using computers in instruction.
6. Attempts to integrate computers into the curriculum should consider similar attempts to integrate calculators.

Rationales for making some major curriculum changes are presented in some articles (e.g., Norris, 1981). A slew of other articles provides specific suggestions for teaching particular topics better with the use of a microcomputer (e.g., Inman and Clyde, 1981); many include listings of computer programs.

Research with Computers

We know from the research of the past 20 years that computers can be used effectively in mathematics instruction. Some evidence exists on most of the types of use. Much of this evidence is appropriate to microcomputers, although few studies thus far have appeared using microcomputers. Unlike the situation with calculators, where an emotional fear of their use is evidenced, microcomputers are generally accepted as a valid educational tool. The antagonism toward the use of calculators led to a plethora of studies to ascertain their effects and reassure parents and teachers that they would not harm achievement. The willing acceptance of microcomputers has not created this need for research evidence; consequently, efforts are focused far more on developing activities and materials for their use.

PRISM data have already been cited, offering strong support for including many computer literacy topics and an emphasis on computers in the curriculum of the 1980s. When the results from the National Assessment of Educational Progress are considered, however, we find that 13- and 17-year-olds were weak on both flowcharting and programming items. The levels of performance were about what would be expected by chance alone. In fact, only 14 and 12 percent of the 13- and 17-year-olds, respectively, indicated they had used computers when studying mathematics.

Selecting a Microcomputer

Deciding which microcomputer to purchase can be difficult. Many articles (e.g., North, 1979) provide comparison charts, listing cost, components, and features for various computers. These should be checked prior to ordering. Two general rules are also suggested:

1. Try to determine the final system you expect to own, and plan toward it.
2. Try to talk with owners or users of all the systems you are considering.

Software Considerations

The NCTM has published *Guidelines for Evaluating Computerized Instructional Materials* (Heck et al., 1981). It provides guidelines and forms for software documentation as well as evaluation. It suggests consideration of such factors as: level or range; type of interaction with learner; execution time; instructional uses; flexibility of adjusting it to suit a particular class or student; possibility of intervention by the teacher; quality of directions; format; content focus, significance, and validity.

A Final Suggestion

The number of articles and books about microcomputers is high and growing. Many could be valuable to teachers in all areas of the curriculum; some are specific to mathematics instruction. You can't read them all — but arrange for some sharing time with other teachers to exchange information on how to use computers effectively.

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Software for microcomputers is now being reviewed in the *Mathematics Teacher.*

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