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ABSTRACT

This conference was designed to identify salient elements of the national science/mathematics teacher shortage, add corollary data to the existing body of knowledge, and to influence and guide future NIE research in the area. The proceedings include: welcoming and keynote addresses by, respectively, Manuel J. Justiz and T. H. Bell; five commissioned research reviews and analyses; six program papers; and edited transcripts of discussions following each paper. The research reviews and analyses include: "Supply and Demand for Science and Mathematics Teachers" (Betty Vetter); "National Needs for Science and Technology Literacy: The Army as a Case Study" (Wilson Talley); "Research in Science Education" (Wayne Welch); "Taking Mathematics Teaching Seriously: Reflections on a Teacher Shortage" (Jeremy Kilpatrick, James Wilson); and "Preparation of Teachers: Myths and Realities" (Anne Flowers). The program papers include: "The Teacher Shortage in Mathematics and Science: The Los Angeles Story" (Rosalyn Heyman); "PRISM--A Program for Students Built upon Professional Growth Experience for Teachers" (Douglas Seager); "Teacher Shortage in Science and Mathematics: What is Houston Doing about it?" (Patricia Shell); "Argonne Supports Precollege Education in Science and Mathematics" (Juanita Bronaugh); "Science Museums and Science Education" (Bonnie VanDorn); and "Policy Alternatives: Education for Economic Growth" (Roy Forbes). The concluding section discusses possible research and practice directions. (JN)

# TEACHER SHORTAGE IN SCIENCE AND MATHEMATICS: MYTHS, REALITIES, AND RESEARCH

Proceedings of a Conference Sponsored by the
National Institute of Education,
in Washington, D.C.,
February 10-11, 1983

*Edited By*

John L. Taylor
National Institute of Education

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# FOREWORD

A shortage of certified and qualified science and mathematics teachers is one of the most visible and critical problems faced by our Nation's schools. Local, State, and Federal governments; education and science associations; universities; the military; and private industry have all turned their attention toward this problem. Collectively, these bodies form a national movement with the common goal of ensuring the Nation's role as a world leader in education, science, engineering, and technology. The approaches taken to reach this goal, however, are as varied as the movement's participants. Hence, there is a need to identify and describe the most viable alternative and to focus the effort. The Improvement of Science and Mathematics Education (ISME) Team of the National Institute of Education (NIE) was established to fill this need.

The ISME Team is charged with planning and overseeing research on the science and mathematics teacher shortage. The team's specific aims are: (1) to determine and report on the state of the problem, its related issues and solutions; (2) to conduct a national conference on the science and mathematics teacher shortage; and (3) to prepare a research agenda on methods of alleviating the shortage. A unique aspect of the team's work is its emphasis on teachers and the nature of teaching in science and mathematics.

One of the team's primary tasks has been completed. A conference entitled, "Teacher Shortage in Science and Mathematics: Myths, Realities and Research," was held in the Nation's capital in February 1983. The conference was designed specifically to identify the salient elements of the national science and mathematics teacher shortage, add corollary data to the existing body of knowledge, and influence and guide future NIE research in the area. The conference participants represented people working on all facets of the teacher shortage.

The distinguished contributors to the conference proceedings, agreeing that teachers and teaching of science and mathematics is in a state of crisis, applied their individual and collective knowledge and insights to the problems of our day. They focused on possible myths surrounding the teacher shortage, the realities and research concerning science and mathematics education, and the programmatic solutions operated within and outside of school settings.

The conference proceedings include a Welcoming Address by Manuel J. Justiz, NIE Director; a Keynote Address by the Honorable T. H. Bell, United States Secretary of Education; followed by five commissioned research reviews and analyses; six program papers; and the edited transcripts of the discussions that followed each paper. The concluding section provides possible research and practice directions prepared as part of the conference summary document.

A point of information. In the proceedings there may exist some discrepancies between the conference papers and the discussion of the papers. The discussions depict responses to the conference presentations and earlier drafts of the papers. The paper authors were encouraged and did make substantive revisions of their papers after the conference for this publication.

Educators at all levels, researchers, legislators, individuals from business and industry, and others will appreciate the conference contributors' analyses, historical reflections, research and curricula reviews, statistics, case studies, debates, and suggested directions for action.

We express appreciation to Lee Shulman, who served as moderator of the conference responsible for the "intellectual glue" that connected presentations and discussions to the primary themes of the conference. We also thank Thomas Good and Gail Hinkel for producing an outstanding summary document two months after the conference. Over 1,000 copies of the summary document have been distributed worldwide and to 50 States. Appreciation is also extended to the conference contributors for their professional time and permission to print a stimulating collection of papers and discussions. Finally, we are grateful to the NIE staff, in particular Virginia Koehler, and to Caroline Watler and Ramsey Sa'di of Dingle Associates, Inc. for their excellent contributions to the conference and proceedings.

Shirley A. Jackson
Associate Director

John L. Taylor
Team Leader
Improvement of Science and
Mathematics Education

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# PLENARY SESSION

## WELCOMING ADDRESS

Manuel J. Justiz, Director
National Institute of Education

It is a distinct pleasure for me to welcome you to the National Institute of Education's conference on the status of science and mathematics education. I have had the opportunity to meet a number of you who will be presenting papers and leading some of the discussions. I am very impressed with the caliber of all participants and with the many different views and perspectives that are represented. We are delighted to have you join us in this forum, where we hope to continue a vigorous discussion in an area of tremendous interest and concern to all of us in this country.

I have just returned from a hearing in Albuquerque, New Mexico, held by the Senate Budget Committee, on the issue of mathematics and science. And I am pleased to report to you that the concerns that were expressed by representatives of industry and by the education community are very much in tune with our concerns about the tremendous need for getting qualified mathematics and science teachers in our classrooms as quickly as possible.

Clearly, mathematics and science are critical to our country's future and to its technology and economic prosperity. Technology is changing the structure of the world. Our ability to maintain a strong and sound economy and to compete effectively in the world marketplace will depend largely on our ability to maintain the technological supremacy we have had in past decades.

When we talk about mathematics and science, and when we talk about technology, we also very quickly begin to think of the defense area and the critical role that this country plays in providing for the protection of our allies and other nations that share our views and values. It is clear to us that if we do not keep up, both in industry and in the classroom, it will be, as Nobel Prize winner Glenn Seaborg has noted, "unilateral disarmament."

In the past, we have tended to look on science and mathematics as academic disciplines. This we must continue to do. But we cannot confine ourselves to this narrow view. The roles of science, mathematics, and technology have expanded, and they are now fundamental to enabling all of our citizens to meet the needs of our information-based, technology-oriented world. It is apparent that we are entering a very vital and major technological revolution--an era in which the microcomputer may well become to American homes and families what the pocket calculator became in the 1960's. It is essential that we become literate and informed about technology.

To respond to this demand, we will need to overcome the inertia of ill-prepared students, inadequate laboratory facilities and materials, and the scarcity of qualified science and mathematics teachers.

Consequently, it is imperative that we marshall the tremendous resources of this country to the task of gearing our Nation's schools toward excellence in science and mathematics education. This will involve including our schools, colleges, libraries, museums, military, universities, business, and industry, in the deliberations on how to close the gap between our technologically sophisticated world and the present capacity of our education system.

As befits the current state of knowledge in this area and the appropriate role for Federal Research and Development, our approach in this conference is not to try to arrive at a solution. Rather, it is to find key people, such as yourselves, both presenters and participants, to join us in investigating the problem and considering a national baseline of knowledge on the issues. Following this conference, the National Institute of Education staff will examine the proceedings in order to determine the implications for our future role and for the research agenda that may well be further clarified and refined as a result of the proceedings.

I respectfully challenge you to articulate clearly what you know--the perspectives that you bring to us--concerning the mathematics and science teacher shortage. Help us to clarify the myths and the realities we are confronting and suggest promising research directions.

I trust this will be a productive conference. All of us are looking forward to reading the proceedings, just as we are looking forward to the discussions that will take place today and tomorrow.

## KEYNOTE ADDRESS

The Honorable T.H. Bell
Secretary, U.S. Department of Education

As you meet to discuss the shortage of mathematics and science teachers, it is important for you to consider not only the problems we face today, but those we will be facing over the next 3 to 6 years. To put this in perspective, I would like to emphasize three points:

1. All across the Nation, school boards are increasing high school graduation requirements in mathematics and science. Keep in mind that for each additional year of study required in either of these fields, there will be a nationwide demand for 34,000 additional high school teachers.

2. Teachers are leaving the teaching profession for better paying jobs in the emerging high tech industries. Therefore, we must not only increase the supply of teachers; we must also make teaching more attractive to ensure fewer teacher "dropouts."

3. To date, we have not fully grasped the significance of the microcomputer as a force that will change our entire teaching and learning methods from kindergarten to graduate school. Computers are no longer the fad they were back in the 1960's. John Naisbitt, in Megatrends, reminds us that fads are imposed from the top down and trends come from the bottom up.

It is up to those of us in education to help equip the youth of our Nation with skills, knowledge, and values so that they can meet their duties and responsibilities to the past and future of this Nation. Among other things, we have a responsibility as educators to help America remain the technological leader of the world. As President Reagan observed in his State of the Union address, "We must keep that edge, and to do so we need to begin renewing the basics, starting with our educational system." Mathematics and science education are an important part of past reasons that America rose to international greatness and are extremely important for the continuation and renewal of American life and the attainment of the American dream.

Some groups say there is no shortage of mathematics and science education or of teachers to provide that education. Others say the deficits in both areas are enormous. Obviously, we need to consider what the need will be when we change our emphasis. We must respond to the need for more technical and scientific competence and more scientific and computer literacy. Regardless of what the specific figures appear to say, it seems inevitable that the future of white collar workers, including teachers, will be very strong. It takes time to increase the supply of new teachers and retrain existing ones.

Now I do not mean this as an adverse reflection on our championship Redskin football team--of whom we Washingtonians are very proud--but the fact is that in most of our American elementary and secondary schools, a football hero has more respect than a scholar. Pep rallies receive more attention and are far better attended than a debate meet or any other type of academic competition. We have stressed excellence and competition in athletics but seem to have forgotten them in academics.

Education has misplaced its priorities. Mathematics and science education are indicative of this. For example, a 1980 survey showed that only nine States required 2 years of mathematics for high school graduation, and only one State required 3 years. Other data showed that only 38 percent of high school seniors reported taking 2-1/2 or more years of mathematics and nearly 5 percent reported taking no mathematics at all. Only one-fourth reported taking 2-1/2 years or more of science, while 8 percent had taken no science courses.

H.G. Wells has often been quoted for his observation that history in the 20th century has become a race between education and catastrophe. That observation has never been more true. It seems that we often forget that our children will spend most of their lives in the 21st century, a century of bewildering scientific and technological change. We do not have time to worry about future shock when we are trying to cope as a people with the present shock and dislocation caused by a society in transition from an industrial economy to a high tech, information-service economy. The revolution in information is as profoundly changing society as did the invention of the printing press or the industrial revolution centuries ago. This revolution will make all of us managers of information. It will free us to build and run machines and to pursue better lives in so many other ways...if we are prepared to do so.

High school graduates not proficient in the basic skills will narrow the pool from which future engineers and scientists will be drawn. Furthermore, those students who choose other career fields will not have the preparation to deal with the technology-based issues they will face as workers and citizens in a Nation whose future is linked to technology advances. We are already seeing signs of this with the terribly high percentage of unemployed teenagers and young adults. In the past, students were not made aware that science was important to them personally. The general population of the United States did not understand the importance of a firm grounding in mathematics, science, and the basic academic skills.

A point that no American can afford to miss is that world leadership depends on technological superiority. As the late Premier Brezhnev stated: "The field of scientific and technological progress is today one of the major fronts in the historical battle between the two systems" (Socialism and capitalism).

At the end of World War II, the Japanese recognized and made a commitment to the teaching of mathematics and science and to technological development. They have met this commitment with high academic requirements and standards. In the U.S.S.R., compulsory science includes 5 years of physics and 4 of chemistry. Less than 20 percent of U.S. high school graduates take even 1 year of physics, and less than 40 percent take 1 year of chemistry. Ironically, much of Japan's advance in mathematics and science has been based on curriculum materials developed in the United States in the 1960's.

I want every United States citizen to be aware that many other industrialized countries are providing a more intense, rigorous curriculum for their students. They are getting the results they demand. I fear that students in these countries are working to gain the education that could allow the United States to sink to the status of a second-rate power. We must respond to this massive challenge posed by the other industrialized nations of the world.

The strength of our economic system and the defense of our country are predicated on our dominance in education and technology. To maintain our strength in these areas, and indeed, our national independence, we cannot afford to let skills in these fields degenerate. As philosopher Alfred North Whitehead once wrote: "It is the business of the future to be dangerous; and it is among the merits of science that it equips the future for its duties."

What we all know is that in order to have quality education, we must have quality teaching. I feel that in all subjects of academe, we are not attracting the desired large numbers of bright and talented people into the teaching profession. Most of the other professions and many of the skilled trades pay more than teaching. This has been a problem for years, and I will not belabor the point because I am sure it is one of which you are all aware. I do not believe that anyone could dispute the fact that there ought to be more economic potential in the teaching profession. We desperately need to establish the teaching profession as a prestigious, esteemed, and honorable calling. Promising students and talented teachers already in the profession should be able to move readily through recognition and promotions to command salary and esteem.

On our college and university campuses, we have established a system of academic rank, and it is universally accepted. In academe, we have found it both necessary and desirable to go even beyond this point. We have endowed chairs and distinguished professorships on many campuses. Compare this with the existing system in our elementary and secondary schools. We have a single salary schedule with no salary differential except for years of experience and college credit hours. We have no system in our personnel practices that offers encouragement and opportunity to be recognized as an outstanding professional worthy of distinction in both salary and esteem. We offer little incentive to those who enjoy the life of teaching and who have no desire to seek an administrative position.

I believe we need to establish in American society a new position of "Master Teacher." This new position should be a much esteemed and sought after distinction among teachers. It should provide a step beyond the ranks of beginning teacher and regular teacher, and it should command a salary that is commensurate with other salaries that recognize accomplishment and great worth to American society.

We cannot continue with the status quo and build a truly great teaching profession. The time is long past due for a change.

There is nothing we do in America that is more important than teaching. As we look to the future and the competition we will be facing in a changing and fiercely competitive world, we simply must realize that our youth deserve to be taught by the very best minds we can attract to our schools. In the years ahead, our State legislatures, governors, school boards, administrators, and teacher organizations must take steps to build a truly great teaching profession. There must appear in the law, in the school finance formulas, and in the school board policies across the Nation new provisions that will help us to attract and keep the very best talent available.

It is my hope that what I have been saying about the Master Teacher concept would at least trigger more public debate on what we should do to build a teaching profession to meet the needs of an increasingly complex society. We must make it possible for our most distinguished teachers to command a salary that is competitive with salaries in engineering, law, accounting, and other professions. This will require a big increase in a Master Teacher increment.

Let us now think about and speculate on the enormous impact that the microcomputer and silicon chip will have on all of American education. This is, of course, directly relevant to what we have been discussing concerning the supply of teachers. Consider the following facts. A few years ago, a pocket calculator cost the equivalent of a trip to California. Today, you can get one free with your subscription to a magazine. Given the frantic rate of advance in the computer industry, it is highly probable that, in 2 or 3 more years, we will have teaching computers the size of a billfold that sell for $9.95. It will be possible to carry around an elementary biology, physics, or chemistry teaching computer that will tutor in the requirements of that subject. Students will buy these computers and use them as casually as they now use pocket calculators. These pocket-sized teaching computers will contain much of the coursework and basic information now found in our textbooks. What is more, these pocket teaching computers will have very sophisticated programming that will provide interaction and conversation with the learner.

If you do not believe this to be possible, let me tell you that a prototype was developed by the National Physical Laboratory in England a few years ago. The teaching computer was called "MINNIE." It has more key functions than one sees on a pocket calculator, and it has considerable interactive and tutorial capacity in the teaching of French to English-language-dominant persons and English to French-language-dominant persons.

This era is just around the corner. Competing corporations are going to be producing these pocket-sized teaching computers by the millions. These little units will be very handy to use, and they will be mass produced at so nominal a cost that competing companies are going to rush into the market very soon. This could radically change the scope and sequence of American education.

Now is the time for teachers and administrators in education to face up to the fact that the computer manufacturing commpanies are going to "climb into our sandbox" and start punching us around. Some mathematics teachers are now frustrated with the pocket calculator. The biology teacher, along with the physics and chemistry teachers, should be prepared for students who will come to school with much of the subject matter available in the memory of a pocket-sized teaching computer.

We need to recognize this future potential as a near certainty. We need to realize that the pocket teaching calculator will be upon us in a very short time, and that it is going to rock the foundations of academe. We must grasp the immensity of the computer in education. It is going to lead us to bookless schools, to paperless newspapers. Interactive and tutorial computer programs will tear up the scope and sequence of education as we know it today and reshape it in a manner that may be traumatic to many teachers.

The momentum will be carried by the intense competition of Texas Instruments, Atari, TRS-80, Apple, IBM, and all the rest that are frantically competing for this expanding market. Keep in mind that we spend over $200 billion in this country on our public and private education establishments. This is a market that has the computer companies licking their chops. Parents will spend billions more in addition to taxes and tuition to give their children the demonstrative educational advantages that will be promised on television and in full page advertisements in nationwide magazines.

Now this is crucial to our discussion about mathematics and science teachers because the level of preparation and the subject matter mastery of tomorrow's teachers will demand effective teacher preparation on the university campus.

I did not sketch the computer and the future of education with an intent to tell you that it will be bad for education. I emphasized that it will be what American education will make it--only if we seize the opportunities and shape the events to our advantage. If we do not have both the foresight and insight to grasp the significance of the technological future, we will be left on the sidelines, and the computer companies, with their omnipresent software, will dominate.

This is an exciting as well as frustrating time to be involved in education. I commend our National Institute of Education for sponsoring this conference. We appreciate your participation in it. May you have a rich and rewarding experience.

I look forward to your report and deliberation in helping to sort out the myths and realities posed by the educational challenges of the information and high tech age.

## CONFERENCE ORIENTATION

Lee Shulman, Professor of Education and Psychology
Stanford University

My few remarks fall under the category of "Orientation," but I suspect this group needs very little orientation to what it is we are going to be discussing over the next 2 days.

Many of us felt that the late 1950's and the 1960's was a period of renaissance for science and mathematics education in this country--a period when the ferment and the excitement over reconceptualizing the mathematics and science curriculums, and the social studies and behavioral science curriculums in schools reached a pitch that it had never before achieved and has not achieved since. During this period, many of us read an essay by Jerome Bruner called "The Act of Discovery." In it, Bruner told of the observation made by a British philosopher that there were basically three kinds of things in this world--you will notice they come in threes, inevitably.

- First, there are troubles--troubles that breed feelings of disequilibrium, of unease, and of discomfort, leaving us with a sense that there is something wrong that ought to be responded to, but little else.
- Then, there are puzzles--and puzzles have a very clear structure, a very precise formulation, a very elegant design.
- And finally, there are problems. And problems are what we have when we find an appropriate puzzle to lay on one of our troubles.

What we are here for in these 2 days is not merely to acknowledge that, as Robert Preston sang so persuasively in "The Music Man," "we've got troubles" in this country in the area of science and mathematics education. That will yield simply breast-beating and rhetoric. Rather, we are here to find appropriate ways of transforming those troubles into problems--problems that we can then address intelligently through policy, through inquiry, and one would hope, through policies grounded in appropriate research and inquiry. Our goal is to help move our national agenda from soul-searching and anguish to carefully crafted policies in research.

The role of research in this kind of activity is to inform practice and policy, to provide a basis for evaluating policies once they are put in place, and--I think this is terribly important--to be informed by practice. As you look around this room, you find people not only from the research community but from the communities of business, industry, public and private education at all levels, and the military--people in the varieties of practices that we need to listen to and talk with in order to produce a body of research in this country that will both inform practice and learn from it.

The focus of our meeting is the profession of teaching, especially with reference to science and mathematics, the conditions of that profession, and the education of teachers. I say this because the planners of this conference did not try to include in this 2-day agenda every possible topic relevant to the problems of science and mathematics education. For example, for the last decade there has been a rich and exciting body of work under way in the cognitive psychology of learning in science and mathematics. Although this is a very important body of work that, at some point in the near future, must be integrated with the deliberations of this conference, it will not be addressed explicitly during these 2 days. An important body of work is also developing on the uses of technology instruction and in teacher education. That, too, will not be addressed explicitly in the next two days.

We have learned from our experience in research that the only way to make real progress on a question is to delimit it, or set some boundaries on it. This may dissatisfy those who want to do everything at once, but without delimiting the problem, you cannot have sufficient precision of deliberation and debate, dialogue, and investigation to move ahead.

I think you have to recall that the meaning of the word "discipline" is itself an interesting pun. It means not only a delimited body of inquiry, but also reflects the discipline of the investigator who forces himself or herself to work within the procedural rules of a field and to not try to do everything at the same time. Clifford Gertz put it very nicely when he said: "You don't have to know everything to understand something." Our goal today and tomorrow is to come to understand some very important things.

The dilemmas that Secretary Bell described can sometimes best be appreciated by a particular individual case. Let me tell you of such a case. Last summer, I had a conversation with a young woman who was beginning a 12-month program at Stanford University leading to certification as a science teacher. She has a bachelor's degree in physics, with distinction, from UCLA and had worked for a year in the aerospace industry in southern California. She had come to Stanford to study to be a teacher. One of the things the Stanford faculty does as part of student orientation to teaching is to pass out the salary schedule of the Palo Alto public schools. Student teachers deserve a sense of what to look forward to when they finish their program. This young woman looked at the salary schedule and said: "You know, if I can get 90 graduate hours and work for 12 years, I can end up earning as much as I made last year." And she just smiled and shrugged. She is still in the program.

This young woman's attitude is one of the things we have to come to understand. What are the sources of gratification? What are the motivations that bring talented young people into our profession? What are the conditions that we need to foster to bring more people in? What are the conditions we have to create in the field to ensure that young women and men will still be teaching not only 2 or 3 years from now, but 10 or 15? These are the kinds of questions that we are to address.

We begin with two papers that examine questions of supply and demand—questions of manpower. Now, you might say: "Why in the world, when we have these very serious policy questions to deliberate, should we begin by merely describing what the situation is?"

I am reminded of a letter to the editor in Science magazine about 10 years ago from a British operations researcher named C.D. Waddington, who is considered in Great Britain, I am told, to be the father of operations research in that country. In his letter, Waddington was describing what operations research was like during World War II, when, in effect, they had to invent it as they went along. Waddington stated: "You know, too much emphasis has been placed on the fancy equations we had to generate in order to do our work. It is important to remind everyone that perhaps the most important thing we learned was the importance of first describing carefully and with great precision what the current state of affairs was whenever we addressed a new problem. We often found that when we had carefully described what was currently the state of affairs, we didn't need complex solution strategies; it was perfectly clear what we ought to do next. And certainly, even when we did need complex strategies, we couldn't proceed without knowing what the current state of affairs held."

Following the advice of Mr. Waddington, we will begin with a careful consideration of what the current state is with respect to the availability and likely availability of teachers of science and mathematics.

# SESSION II
# SCIENCE AND MATHEMATICS: SUPPLY AND DEMAND DATA

## SUPPLY AND DEMAND FOR SCIENCE AND MATHEMATICS TEACHERS

Betty M. Vetter, Executive Director
Scientific Manpower Commission

There is abundant evidence of a shortage of qualified mathematics and science teachers in the secondary schools, and some evidence of a diminishing quality as well. A potential shortage of scientists in some specialties, as well as of engineers and technicians, will be exacerbated by a decline in pre-college mathematics and science education. President Reagan recently described the problem as "serious enough to compromise America's future ability to develop and advance our traditional industrial base...." (Reagan, 1982).

This paper examines the evidence pertaining to the shortage of qualified science and mathematics teachers and to a drop in quality; discusses some of the reasons why the shortage has occurred, the accompanying indicators of change in student achievement, and the consequences of a continuation in this shortage; and summarizes some of the steps being taken to alleviate the problem. Comparisons are made with the educational processes in other nations with whom the United States is in competition, both in defense and trade.

### EVIDENCE OF SHORTAGE OF SCIENCE AND MATHEMATICS TEACHERS

#### Surveys

In the fall of 1980 and again in the fall of 1981, the 50 State science supervisors were asked to assess supply and demand for secondary teachers of science and mathematics (Howe and Gerlovich, 1982). Survey results indicated that shortages reported for 1980-81 had worsened by 1981-82.

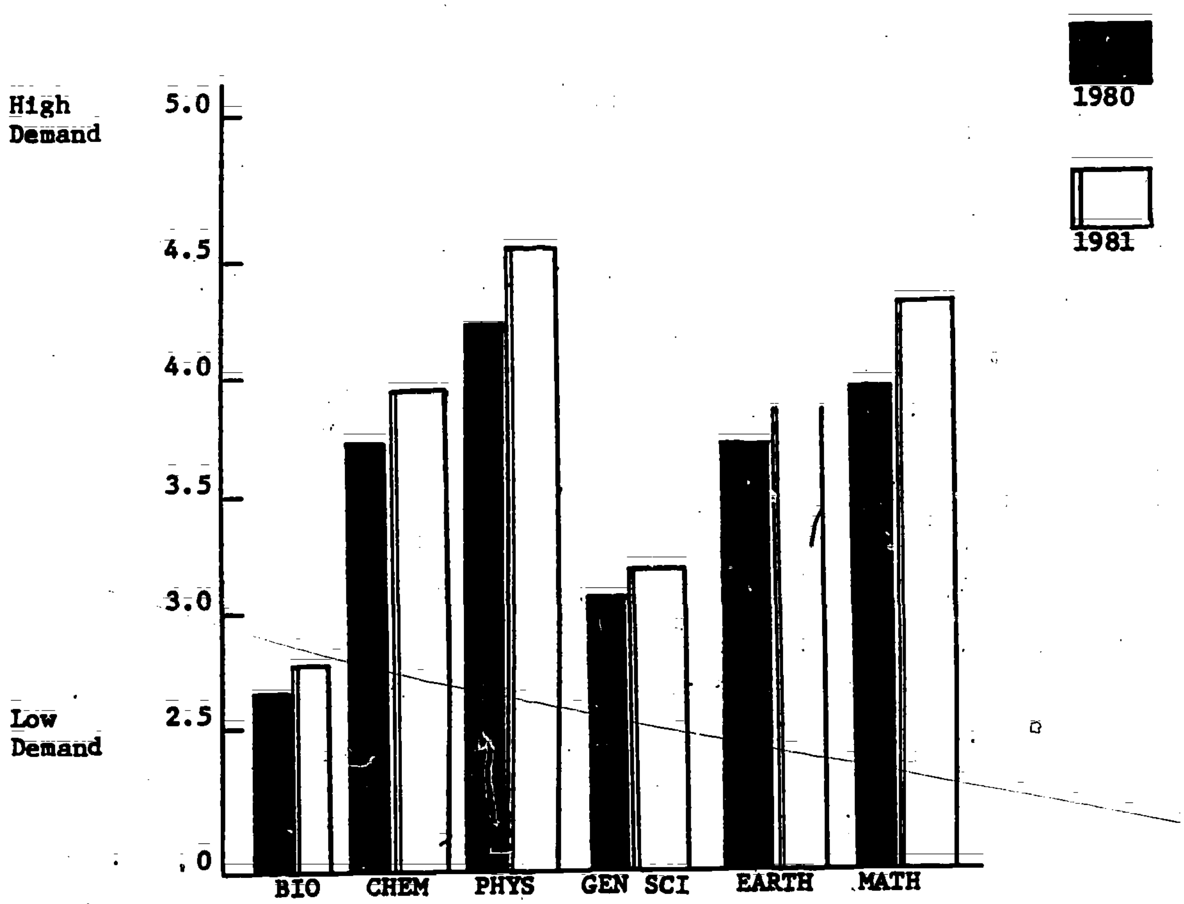
For 1980-81, 43 of the 50 supervisors reported a shortage or critical shortage of physics teachers; 35 reported similarly for mathematics teachers and chemistry teachers. The supervisors reported 447 vacancies for chemistry teachers. These budgeted positions were unfilled because no qualified candidates were available. However, evidence suggests that this survey probably underestimated the shortage since positions filled by unqualified candidates usually were not reported as vacancies.

For 1981-82, a physics teacher shortage had become critical in 27 States. For mathematics, 43 supervisors reported either a shortage or critical shortage, and the number reporting shortages of chemistry teachers climbed to 38. Only eight States reported having an adequate supply of chemistry teachers, with two more reporting a slight surplus and three reporting a surplus.

A 1982 survey of placement directors, as shown in Figure 1, as indicated on a scale of 0 to 5, confirms that the shortage of mathematics and science teachers is critical and worsening.

Figure 1

Demand for Science/Mathematics Teachers




Source: Howe and Gerlovich, 1982.

In December 1981, the National Science Teachers Association (NSTA) surveyed 600 colleges and universities with teacher training programs. NSTA reported a 77 percent decline from 1971 to 1980 in the number of mathematics teachers, and a 65 percent decline in the number of science teachers prepared to teach in secondary schools (See Table 1). Further, the study found that in addition to a severe decline in the supply of persons trained to teach science and mathematics, the fraction of those trained who were entering teaching had also declined. The combined effect was a 68 percent reduction in newly employed science teachers and an 80 percent reduction in newly employed mathematics teachers since 1971, as shown in Figure 3 (NSTA, 1982).

Table 1

Index of Science/Mathematics Teacher Supply Data 1971-80

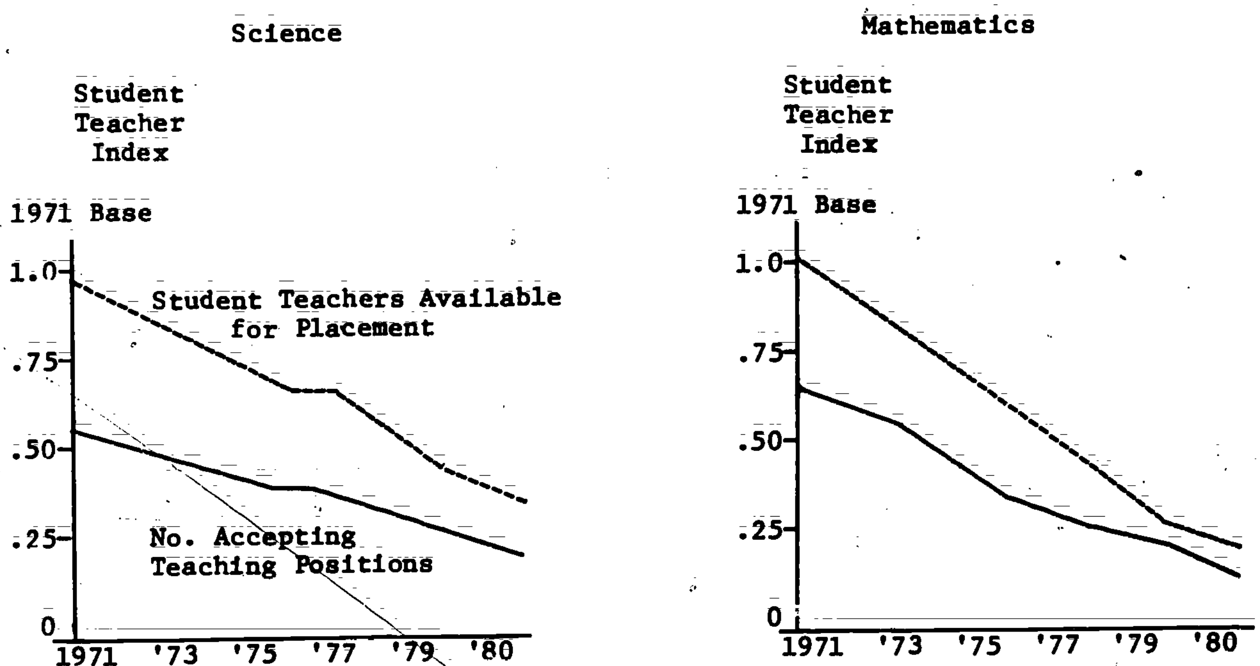
| | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 |
|---|---|---|---|---|---|---|---|---|---|---|
| Science | | | | | | | | | | |
| Graduating Teachers | 100 | 90 | 85 | 75 | 65 | 65 | 55 | 50 | 40 | 35 |
| Percent Entering Teaching | 59 | 58 | 58 | 55 | 56 | 59 | 56 | 52 | 54 | 54 |
| Mathematics | | | | | | | | | | |
| Graduating Teachers | 100 | 91 | 86 | 73 | 60 | 45 | 36 | 27 | 27 | 23 |
| Percent Entering Teaching | 63 | 68 | 64 | 65 | 62 | 61 | 63 | 59 | 60 | 55 |

Source: NSTA, 1982.

The effect of these changes is shown even more forcefully when the data are in grapic form (See Figure 3).

Figure 2

Student Teacher Supply Index Based on 1971 Supply




Source: NSTA, 1982.

Another NSTA survey of a random sample of 2,000 secondary school principals, also conducted in December 1981 and analyzed by James Shymansky of the University of Iowa, requested information on the qualifications of those science and mathematics teachers who were being hired (Klein, 1982). The survey found that 50.2 percent of the newly employed teachers were not qualified to teach science or mathematics but were employed on an "emergency basis" because no qualified teachers could be found (See Table 2).

The findings, when examined by census regions, show severe problems in States where high technology industries require the best-trained science and mathematics personnel. For example, in the Pacific States, a whopping 84 percent of the science and mathematics teachers newly employed in 1981 were unqualified in those subjects. The eastern seaboard and the gulf coasts also show higher than average levels of unqualified teachers.

Table 2

Percentage of Newly Employed Unqualified Science/Mathematics Teachers

| Census Region | 1980-81 | 1981-82 |
|---|---|---|
| Pacific States | 75% | 84% |
| Mountain States | 44 | 43 |
| West North Central States | 26 | 43 |
| West South Central States | 63 | 63 |
| East North Central States | 23 | 32 |
| East South Central States | 43 | 40 |
| Northeastern States | 11 | 9 |
| Middle Atlantic States | 40 | 46 |
| South Atlantic States | 48 | 50 |
| All States | 45% | 50% |

Source: NSTA, 1982.

The National Center for Education Statistics (NCES) conducted a survey of teacher demand and shortages during the 1978-79 school year and found that a shortage of 600 teachers represented 2.4 percent of all employed teachers in the physical sciences (NCES, 1982a). In mathematics, the shortfall of 900 teachers represented only 0.6 percent of employed mathematics teachers, but the proportional shortfall has climbed well above that figure since 1979. (See Table 3 for more details.)

Table 3

Employed Teachers and Teacher Shortages, Spring 1979

| Field of Assignment | Employed Teachers | | Shortages | | Shortages As a Percentage of Employed Teachers |
|---|---|---|---|---|---|
| | Number | Percent of all Teachers | Number | Percent of all Shortages | |
| Total | 2,552,000 | 100.0 | 11,300 | 100.0 | .4 |
| Preprimary | 99,000 | 3.9 | 700 | 6.3 | .7 |
| Primary and general elementary | 899,000 | 35.2 | 2,600 | 23.3 | .3 |
| Art | 57,000 | 2.2 | 100 | .8 | .2 |
| Basic skills and remedial education | 9,000 | .3 | - | - | - |
| Bilingual education | 22,000 | .9 | 400 | 3.7 | 1.9 |
| Biology | 30,000 | 1.2 | 100 | .9 | .3 |
| Business | 45,000 | 1.8 | 200 | 1.8 | .4 |
| English language arts | 188,000 | 7.4 | 200 | 2.2 | .1 |
| Foreign languages | 53,000 | 2.1 | 100 | 1.1 | .2 |
| General science | 76,000 | 3.0 | 200 | 2.1 | .3 |
| Health, physical education | 158,000 | 6.2 | 100 | 1.2 | .1 |
| Home economics | 36,000 | 1.4 | - | - | .1 |
| Industrial arts | 41,000 | 1.6 | 600 | 5.3 | 1.4 |
| Mathematics | 150,000 | 5.9 | 900 | 8.3 | .6 |
| Music | 87,000 | 3.4 | 200 | 1.4 | .2 |
| Reading | 73,000 | 2.9 | 300 | 2.8 | .4 |
| Physical sciences | 25,000 | 1.0 | 600 | 5.5 | 2.4 |
| Social studies/social sciences | 143,000 | 5.6 | 100 | .8 | - |
| Special education | 219,000 | 8.6 | 3,200 | 28.3 | 1.5 |
| Vocational education | 101,000 | 4.0 | 300 | 2.9 | .3 |
| Other | 39,100 | 1.5 | 100 | 1.1 | .3 |

Source: National Center for Education Statistics, 1982a.

Number of New Graduates

Nationwide, the number of new teachers graduated in the past decade has dropped from 36 percent to 21 percent of all college graduates. This is not surprising since a teacher surplus has been apparent in the placement statistics for several years. But the drop in science and mathematics education majors has been even greater. The number of education graduates with a major in mathematics (now only 0.5 percent of all education majors) dropped 64 percent, from 2,217 in 1971 to 798 in 1981, while the number of science education graduates dropped 33 percent, from 891 in 1971 to 597 in

1981 (NCES, 1982b). This number includes biology teachers, chemistry teachers, physics teachers, earth science teachers, and general science teachers.

Finally, only 5 percent of all college-bound seniors in 1982 (2.2 percent of the males and 7.4 percent of the females) indicated plans to major in education (NCES, 1982c), and only 1.3 percent of all education majors graduating in 1981 had majored in science or mathematics education (NCES, 1982b).

Thus, it is apparent that there is a severe and worsening shortage of science and mathematics teachers for secondary schools and that present enrollment trends do not offer hope that the situation will change over the next few years.

## Shortages in the States

Some States and even some cities report far more difficulty in filling their science and mathematics teacher positions with qualified candidates than do others. No national data are available on a State-by-State basis, but several States have made some surveys of their own.

In North Carolina colleges and universities each year report to the State Department of Public Instruction the number of completions in teacher education, and the superintendent of each school district reports a vacancy count by field. However, mathematics teacher positions filled by teachers not certified in mathematics are not considered to be openings.

An analysis of these reports over the past 20 years by Robert T. Williams of North Carolina State University indicates that the percentage of new mathematics teachers as a fraction of all new secondary teachers has declined steadily since 1967 (Williams, 1981). Further, the number of reported vacancies for mathematics teachers has been declining since 1969, and, in most years, the number of new mathematics teachers has exceeded the number of vacancies. However, the same analysis reveals that in none of the 20 years were more than 58 percent of the prior year's graduates actually teaching in the fall, and the proportion fell as low as 20 percent.

The result of the effort over the years to fill every classroom with someone, whether qualified to teach the subject or not, has resulted in a situation in which only 55 percent of North Carolina's 4,700 mathematics teachers are certified in mathematics. Among the noncertified mathematics teachers, 21 percent taught a full load of mathematics classes, while others taught only a partial load (See Table 4). Many of the noncertified mathematics teachers were certified in social studies, physical education, grammar, science, or business.

Table 4

Certification Status of North Carolina Mathematics Teachers

| Number of Mathematics Sections | Teachers with Mathematics Certification | Teachers Without Mathematics Certification | All Mathematics Teachers |
|---|---|---|---|
| 1 | 54 | 494 | 548 |
| 2 | 113 | 680 | 793 |
| 3 | 174 | 335 | 509 |
| 4 | 274 | 179 | 453 |
| 5 | 1,557 | 266 | 1,823 |
| 6 | 395 | 161 | 556 |
| 6 | 11 | 7 | 18 |
| Total | 2,578 | 2,122 | 4,700 |

Source: Williams, 1981.

Also of interest are the teaching assignments for certified and noncertified mathematics teachers as shown in Table 5.

Table 5

Mathematics Teaching Assignments

| | Teachers Certified in Mathematics | Teachers Not Certified in Mathematics |
|---|---|---|
| Junior High/Middle School | 1,759 | 1,796 |
| High School General Mathematics | 919 | 800 |
| Algebra 1 | 1,410 | 93 |
| High School College-Prep | 1,723 | 52 |
| Remedial Mathematics | 138 | 307 |

Source: Williams, 1981.

The Virginia State Council of Higher Education reports, based on a survey of the 141 school systems in that State (133 reporting), that "The supply of teachers available to hire is not sufficient to meet current demand in particular fields." Almost half of the divisions in the State said they had extreme difficulty finding mathematics teachers, more than one third had problems finding teachers of earth science, and one fourth reported extreme difficulty finding qualified teachers for chemistry and physics courses. Almost half of the earth science teachers in the State were uncertified in the field, despite a 6-year-old regulation that all earth science teachers be endorsed by the 1982-83 school year. Seven percent of the State's chemistry teachers did not meet the requirements for certification in that field.

The number of students graduating from the State's 33 State-approved college education programs fell 25 percent in the last 4 years, the number of student teachers in science and mathematics decreased threefold in science and fourfold in mathematics from 1971 to 1980, and only half of the student teachers have been entering the teaching profession after graduation (Moore, 1982).

In New Hampshire only one 1982 college graduate in the State planned a career in mathematics teaching. In 1980, there were 41 openings for mathematics teachers in New Hampshire high schools, but only six graduates of teacher education programs throughout the State sought mathematics teacher certification ("Math Teachers Scarce," 1982).

Data from the National Council of Teachers of Mathematics' "Mathematics Shortage: Fact Sheet" in September 1982 reveal the following about some of the other States:

- Missouri. Only about half of the 80 prospective mathematics teachers who were to graduate from Missouri's teaching institutions were expected to be teaching the following fall, although at least 200 vacancies were expected in the State. The number of emergency certificates issued in 1979 was up 43 percent over 1978.

- New York. Only 32 graduating college seniors planned to teach junior or senior high mathematics in 1982.

- California. Among more than 400,000 students in California's public four-year institutions in the spring of 1982, only 97 were preparing to be secondary mathematics teachers.

- Texas. In 1982, 20 graduates were certified for mathematics teaching, but only 7 entered the field.

- Maryland. A survey by the State Department of Education at the end of the 1979-80 school year estimated that 50,000 secondary students received their mathematics instruction from more than 400 teachers who were not certified to teach secondary mathematics. In 1982, only 17 new mathematics teachers graduated in the State, and 8 entered teaching.

- Connecticut. The State lost 100 mathematics teachers in 1982 through retirement and job shifts, while only 28 mathematics teachers graduated from the 14 State institutions.

- New Jersey. The State Department of Education has declared an emergency shortage of mathematics teachers in 17 of New Jersey's 21 counties. This emergency designation permits districts to use unlicensed teachers--some without a bachelor's degree--to teach mathematics.

- Iowa. The number of graduates prepared to teach mathematics dropped from 234 in 1970 to 60 in 1979. The number of vacancies during that period fluctuated between 200 and 250 each year, with the smaller school districts having the most severe shortages.

- Mississippi. According to the State Superintendent of Education, State institutions do not even come close to providing the 400 to 500 mathematics teachers that are needed.

Teacher Exodus to Industry

Compounding the problem of an undersupply of new graduates in science and mathematics education is the serious exodus of experienced teachers to industry. According to an NSTA survey of science teachers, the average age of science/mathematics teachers is 41, and the average number of years of experience is 16. However, almost five times more science and mathematics teachers left teaching last year for employment in nonteaching jobs than left to retire. If the present exodus of qualified secondary school science and mathematics teachers continues at the 1980 and 1981 rate of 4 percent per year, there will be a net loss of 35 percent by 1982 (NSTA, 1982). Another NSTA survey found that one in four teachers among the younger faculty plan to leave teaching completely (National Science Foundation--NSF--1982a & b).

Further, a survey in North Carolina found that those planning to leave predominantly are those who are best qualified, while those planning to continue a career in teaching are those least qualified on the basis of preparation and test scores (Williams, 1981). Although there is no documentation, it appears probable that those who have left teaching in the past few years also are among those best prepared in science and mathematics and therefore most desirable as employees for industry.

The reasons for the teacher exodus to industry are generally so obvious as to need no explanation--higher salary levels, more opportunities for advancement, an environment conducive to accomplishment, adequate equipment, and, perhaps most important of all, more respect from society.

A quick look at comparative starting salaries at the end of a bachelor's degree indicates the value society has placed on teaching compared with other science, mathematics, and engineering activities. A starting teacher in 1982 averaged about $13,000 a year. Mathematics majors going to government or industry averaged $21,300; computer scientists, about $25,000; chemistry majors, $21,000; and engineers, more than $25,000. Only biology majors, at $16,000, came even close to the teacher salary levels.

## QUALITY OF NEW SCIENCE AND MATHEMATICS TEACHERS

The drop in the quantity of mathematics and science teachers appears to be accompanied by a drop in the quality of new graduates preparing for secondary teaching. Although quality is much harder to measure than quantity, some indicators of quality can be examined. One of the most obvious is the test scores of students planning majors in education.

The College Board reports that among college-bound seniors in 1982, the average score on the verbal portion of the Scholastic Aptitude Test (SAT) was 426 and that on the mathematical portion was 467. Among students indicating plans to major in education, the verbal scores averaged 394 and the math 419. Thus, as a group, students planning to teach are considerably below average in this measure of quality (College Entrance Examination Board (CEEB), 1962-1982). The scores on the Graduate Record Examination and the National Teacher Examination also indicate that students currently enrolled in teacher education programs are the least competent in comparison with those preparing for other professional careers.

Further, the least competent of the teacher education graduates appear to make up the bulk of those who plan to remain in teaching. For example, a study of teacher recruitment, selection, and retention in North Carolina found a dramatic difference in the teaching plans of those who were highest and those who were lowest in ability. Of those in the upper 20 percent of measured academic ability, only 26 percent intended to teach at age 30, contrasted with 60 percent of those with the lowest academic ability (CEEB, 1962-1982).

The National Center for Education Statistics confirms that the number and academic standing of high school seniors planning to major in education were lower in 1980 than in 1972. Also, as shown in Table 6, the academic records of both women and men planning an education major were lower than those of their 1980 classmates who were planning to major in other fields (NCES, 1982c).

Based on an analysis of data collected in the 1980 High School and Beyond study and in the National Longitudinal Study of the High School Class of 1972, NCES examined cognitive test scores, questionnaires about backgrounds, high school experiences, and the plans of these two groups of students. Ten percent of the women college aspirants planned to major in education in 1980, down from 18.8 percent in 1972. Among the men, the segment planning eduation majors declined from 6.0 percent in 1972 to 3.4 percent in 1980. About three times as many women as men planned an education major, and white women made up about 67 percent of all students planning such a major. White males were second (19 percent), followed by black females (5 percent), Hispanic females (3 percent), and others.

Students planning to major in education had lower scores than other college aspirants on reading, vocabulary, and mathematics tests; their grade point averages were lower than those of students planning other majors, and the number of mathematics and science courses taken in high school was less for education majors than for others, as was the proportion of courses taken that were in academic subjects. Although these differences in academic qualification are more pronounced among males than among females, they apply in both cases.

Table 6

Mean Academic Preparation Measures of College Aspirants, by Sex and Intended Major: 1980

| Academic Preparation Measure | Total | | Male | | Female | |
|---|---|---|---|---|---|---|
| | Education Major | Other Major | Education Major | Other Major | Education Major | Other Major |
| Test Scores | | | | | | |
| Reading | 52.31 | 54.77 | 51.86 | 55.13 | 52.45 | 54.42 |
| Vocabulary | 51.69 | 54.55 | 51.75 | 55.20 | 51.70 | 53.91 |
| Math | 51.54 | 55.02 | 51.79 | 56.58 | 51.46 | 53.51 |
| Grade Point Average* | 6.25 | 6.36 | 5.79 | 6.18 | 6.39 | 6.53 |
| No. of Mathematics Courses | 2.53 | 3.12 | 2.50 | 3.30 | 2.53 | 2.95 |
| No. of Science Courses | .62 | .94 | .74 | 1.09 | .59 | .78 |
| Proportion in Academic Program | .55 | .66 | .47 | .68 | .58 | .64 |

*Self reported, on a scale of 1 to 9.

Source: National Center for Education Statistics, 1982c.

The mathematics tests used for the class of 1972 and for the class of 1980 were different and cannot be compared. However, comparison of scores on reading and vocabulary tests reveal a drop across time (See Table 7). Reading and vocabulary levels may not be the best indicators of the quality of potential educators in science and mathematics, but it is hard to see how effective teaching in any subject can occur without the teacher having these skills.

Equally distressing is the proportion of all high school courses taken that were in academic subjects. Among males planning education majors, less than half of all high school coursework was in academic subjects, and for females, the proportion was only 58 percent.

Table 7

Mean Vocabulary and Reading Test Scores* of College Aspirants by Sex and Intended Major, 1972 and 1980

| Test | Intended Major | Male Seniors 1972 | Male Seniors 1980 | Female Seniors 1972 | Female Seniors 1980 |
|---|---|---|---|---|---|
| Reading | Education | 10.59 | 9.69 | 11.88 | 9.99 |
| | Other | 12.03 | 11.16 | 12.35 | 10.84 |
| Vocabulary | Education | 6.50 | 6.20 | 8.05 | 6.59 |
| | Other | 8.19 | 7.43 | 8.49 | 7.31 |

*Scores are mean formula scores (i.e., number of correct answers adjusted for guessing). Maximum scores are 20 on reading and 15 on vocabulary.

Among women, the differences in academic qualifications between those planning to major in education and those entering other fields appears to be widening. Although this trend is not observed among men, the preponderance of women within the total group makes the finding significant as a tool for assessing the quality of tomorrow's teachers.

There are no data separating potential science and mathematics teachers from other teachers, but as noted, teachers who are not qualified in mathematics and science, but have credentials in other areas of education, are teaching mathematics and science anyway. Thus, we must be concerned with these findings.

Some of the States also have examined the quality of education majors. For example, Virginia reports that the students who enter its education programs tend to have lower entrance test scores than those who enter other college programs (Moore, 1982). Education majors at State universities scored an average of 121 points lower on the combined mathematics/verbal SAT than did their counterparts who graduated in other fields. At private colleges, education graduates scored 80 points below others at their schools.

## CHANGES IN STUDENT ACHIEVEMENT

What information do we have on the effect of these teacher shortages and exchanges on student achievement? We cannot document the relationship, even as to whether it is cause or effect, but we can examine changes in student achievement.

### Test Scores

Since 1962, at the height of the post-Sputnik push for better U.S. mathematics and science training, mathematics scores on the Scholastic Aptitude Tests have fallen steadily, as have the verbal scores (CEEB, 1962-1982). The

National Assessment of Educational Progress (NAEP), in assessments of mathematic skills conducted in 1973 and 1978, found a sharp drop in the ability of students, particularly 17 years old, to apply classroom theory to the numerical problems of everyday life. Information released by NAEP on February 8, 1983, showed a continuing decline in 1980. In this same age group, there has been a steady decline in the science achievement scores as measured in national assessments in 1969, 1973, and 1977 (NAEP, 1978; 1979). This decline also continued in 1980.

Lowered scores have not been limited to the SAT and NAEP testing programs. Consistently lower annual mean scores have been registered on the American College Tests (ACT), the Comprehensive Tests of Basic Skills (CTBS), the Iowa Tests of Educational Development (ITED), and the Minnesota Scholastic Aptitude Test (Jones, 1981).

The decline in average SAT scores may have reached its nadir: The 1981 mean scores were the same as those for 1980, and the scores in 1982 actually increased slightly because of an increase in the scores of Black students. In the 1982 tests, Black students' scores rose an average of 9 points on the verbal side and 4 points on mathematics, while whites gained 2 points in verbal and remained at the same level in mathematics (CEEB, 1962-1982).

Declines in test scores during the 1960's and 1970's have been attributed to a host of problems in home, school, and society. The relationship between the quality of mathematics teachers and student mathematics scores is not quantifiable, but a declining score pattern might, in part, be a cause and, in part, an effect of a shortage of qualified science and mathematics teachers. In other words, a vicious circle.

Some educators and noneducators have attributed this slide to the "new math" programs introduced during the late 1960's, while other studies show that mathematic achievement is higher for students using the new curriculum than for those taught in the traditional way.

## High School Graduation and College Entrance Requirements

Other indicators of student achievement also should be noted. Since 1970, there has been a nationwide trend toward reduction in the number of courses in mathematics and science, as well as in such areas as foreign languages, that are required for a high school diploma. Only one-third of the Nation's 17,000 school districts required more than one year of mathematics and science for graduation in 1982, and one-half of all high school graduates take no mathematics or science at all beyond the 10th grade (NSF, 1982a & b).

Also, as a group, colleges and universities have lowered their requirements for admission. This has necessitated extensive increases in remedial courses in most institutions. Remedial mathematics enrollments at 4-year institutions increased 72 percent between 1975 and 1980, compared to a 7 percent increase in total student enrollments for the same period. In public 4-year colleges, 25 percent of the mathematics courses presently being taught are remedial, and at 2-year colleges, 42 percent of these courses are remedial (NSF, 1982a & b).

A recent study by the National Academy of Sciences also documents a decline in the number of science courses taken by college students who are not specializing in science, engineering, or science-related professions. In 1980, the average nonspecialist college student devoted only 7 percent of coursework to science (NSF, 1982a & b).

The proportion of high school students who have taken science and mathematics courses that would prepare them to enter and understand college courses in this subject has grown smaller, and the proportion who are fully prepared to major in a quantitative field includes less than one-third of all graduates and less than one-fourth of those who enter college.

Two studies by the National Center for Education Statistics provide information on the science and mathematics preparation of high school seniors. One shows the proportion of all seniors in the spring of 1980 who had taken particular mathematics and science courses (See Table 8).

Table 8

Percent of Seniors Who Took Courses, Spring 1980

| Course | Total | Men | Women |
|---|---|---|---|
| Algebra I | 79.3 | 78.7 | 77.9 |
| Algebra II | 49.0 | 51.3 | 47.0 |
| Geometry | 56.2 | 58.0 | 54.6 |
| Trigonometry | 25.6 | 29.9 | 21.7 |
| Calculus | 7.8 | 9.8 | 6.0 |
| Physics | 19.4 | 25.7 | 13.6 |
| Chemistry | 37.3 | 39.2 | 35.4 |

Source: National Center for Education Statistics, 1982d.

Considering that extensive efforts are being made to bring more women into science and engineering fields, their consistently lower participation in mathematics and science courses is troubling. Only 28 percent of those in the 1980 high school class took 3 or more years of mathematics in grades 10 to 12, and only 18.5 percent took 3 or more years of science. About twice that proportion (30.1 percent) completed 2 to 2-1/2 years of science.

The situation is somewhat more promising if we examine the average number of semesters of science and mathematics taken in grades 10 to 12 by high school seniors in 1972 and 1980. In Table 9 we see some increase in participation.

Table 9

Average Semesters Taken by Seniors in Grades 10 to 12

| Subje | All Students 1972 | All Students 1980 | Men 1972 | Men 1980 | Women 1972 | Women 1980 |
|---|---|---|---|---|---|---|
| Mathematics | 3.6 | 4.1 | 4.0 | 4.3 | 3.2 | 3.9 |
| Science | 3.4 | 3.4 | 3.7 | 3.6 | 3.1 | 3.2 |

However, the small increase in science courses taken by women is accompanied by a small decrease among men. Both sexes have increased the number of semesters of mathematics taken during their high school years (Scientific Engineering Technical Manpower Comments, 1982a).

## Cause or Effect?

If good teachers are leaving and only the poorer students are entering teaching, is this a reflection of the low salaries paid to teachers, or are the low salaries a reflection of the quality of teachers and teaching as seen by the taxpayers who must vote, directly or indirectly, on those salaries? Is the inability to raise salaries for teaching fields in short supply attributable to union rules and seniority practices, or is it attributable to citizens' perceptions of science and mathematics fields as not important enough to be taught by qualified teachers? How important is the fact that able women interested in mathematics and science are no longer relegated to teaching as the only acceptable place for their talents?

Why have scores on the mathematics SAT declined so steadily for so long? Is it poor or uninspired teaching that has resulted in the continuation of the score decline long after the original shakeouts of adding significant numbers of students who would not have planned to go to college in earlier years? Or has the continuing decline in test scores resulted in a lessening of quality among those who seek to enter teaching careers? Or are all of these factors intertwined as both causes and effects?

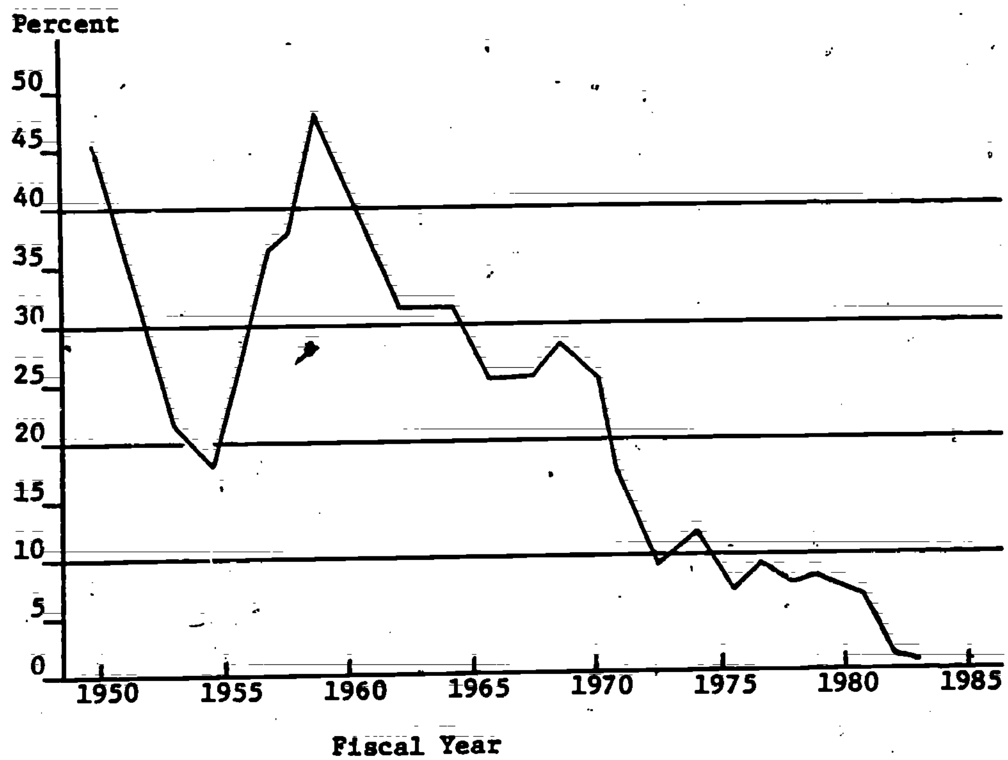
## FEDERAL SUPPORT FOR SCIENCE/MATHEMATICS EDUCATION

Some thoughtful educators believe that only national intervention can bring about solutions to the shortage of mathematics and science teachers. Others believe that education is a State and local responsibility and that the Federal Government should not interfere. Many members of this same group believe that past Federal efforts have been useless, or at least ineffective.

The support of the National Science Foundation for such activities as summer workshops for teachers and other inservice training disappeared several years ago, although the FY 1984 budget includes $5 million for such programs. For the past 2 years, the administration has indicated that previous support for science education was extensive but had not succeeded, and therefore it should be dropped. The facts are just the opposite. NSF support for science and engineering education has declined steadily and steeply for the past 22 years, with science education's share of the NSF budget dropping from a high of 47 percent in 1959 to its present low of 2 percent as shown in Figure 4.

Figure 3

NSF Science Education Funding as a Percent of Total NSF Budget



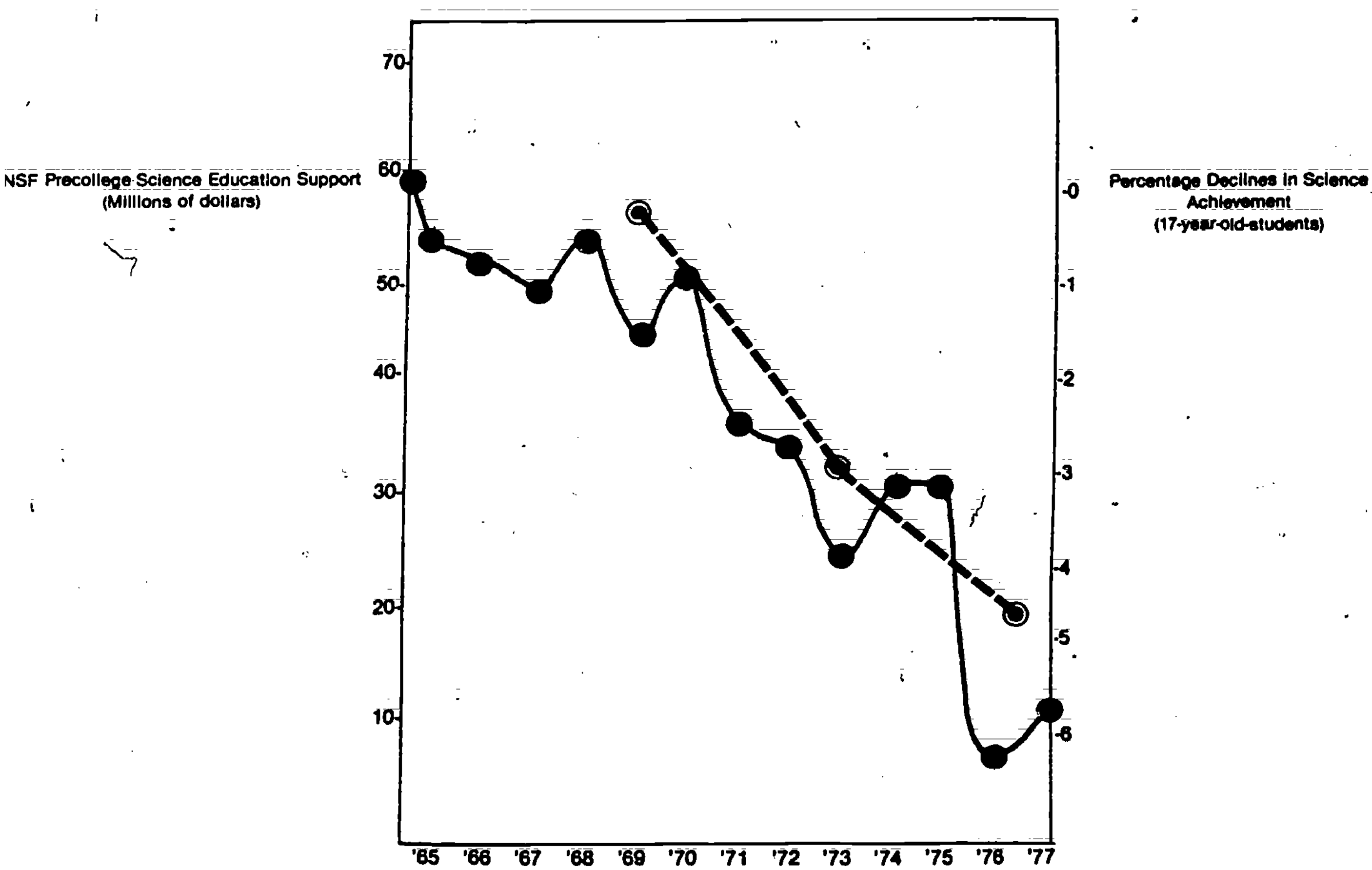

Source: National Science Foundation.

The FY 1984 budget, however, included $39 million for science education, with 51 percent targeted for precollege teacher improvement in science and mathematic activities. Further, $50 million is to be provided to the States in matching grants for 1-year scholarships to retrain unemployed graduates, teachers in surplus fields, and retirees as science or mathematics teachers. This crash program aims to produce 7,000 more teachers per year.

NSF support for precollege science education dropped sharply over a 20-year period, going from 72 percent of the Foundation's science education budget in 1959 to 22 percent in 1980. In 1982, NSF's entire science education division was eliminated. As shown in Figure 5, the decline in NSF support for secondary school science and mathematics correlates quite directly with declining achievement in science as measured by the National Assessment of Educational Progress, and that decline has continued both in budgets and test scores. While this does not necessarily imply a cause and effect relationship, when coupled with other evidence the relationship appears reasonable (Klein, 1982). But especially worrisome is the decline among the high achievers--those who will provide most of the potential pool for science and engineering careers.

Figure 4

Declines in NSF Support of Precollege Science Education Correlated with Declines in Science Achievement at the Secondary Level




Source: National Science Foundation and Education Commission of the States.

## CURRICULUM DEVELOPMENT

Another likely reason for the decline in the quantity and quality of mathematics teachers is that curriculum development activities have been almost dormant since the post-Sputnik efforts. Although there has been much criticism of the "new" curriculums produced with NSF support, a recent study indicates that they have been far more successful than most people realized (Anderson, 1982).

An analysis of 105 studies involving 45,000 students compared those enrolled in new science curriculums and those in traditional curriculums. On every measure, including attitude, achievement, and process skills, students taking the new NSF curriculums scored 14 percent higher overall. Students in the BSCS Biology and Chem Study programs scored 17 percent higher than those in traditional programs. Perhaps most important is that students from low socioeconomic groups scored 24 percent higher using the new curriculums, which gave minority children in those programs a decided edge over similar children exposed to traditional curriculums.

These studies covered a period of several years in the 1960's and 1970's. Few teachers are left in the schools now who are qualified to teach the new curriculums, and almost none have been given the important inservice training since NSF stopped support several years ago. The 1984 budget includes a $5 million program to support workshops and other training activities for precollege science and mathematics teachers. Further, these programs are in serious need of modification and revision to take into account the developments of the past 20 years in such areas as computers, modern electronics, and technology applications. The 1984 budget does not include funds for curriculum development.

Only if teachers find their subject interesting can they transmit that interest to their students. Teachers who are themselves unskilled in their subject matter or who are using teaching materials they do not understand or appreciate are unlikely to inspire interest in the subject among their students.

INTERNATIONAL COMPARISONS

One reason that our problems in mathematics and science education concern us is that we live in an international setting. We can never again restrict our concerns to the confines of our own country. We have potential enemies and potential trade competitors all over the world.

The declining emphasis on science and mathematics in the U.S. school system is in marked contrast to the emphasis of other industrialized countries (NSF, 1982a & b; Wirszup, 1981; Savage, 1981). Japan, Germany, and the Soviet Union all provide their citizens with rigorous training in science and mathematics. Comparative studies in science and engineering education suggest that students in these countries are getting the kind of education that may allow them to overtake the United States in scientific and technological advances with both industrial and military applications.

For example, almost 100 percent of Soviet students complete secondary education, compared with 75 percent in the United States. Compulsory science in the U.S.S.R. includes 5 years of physics and 4 of chemistry; fewer than 20 percent of U.S. high school graduates take 1 year of physics, and only 37 percent take one year of chemistry. The U.S.S.R. offers its students sequences of course material in science and mathematics starting with an intuitive level of understanding and progressing to empirical levels and, finally, to formal axiomatic and theoretical understandings. U.S. students entering these subjects are immediately introduced to abstractions, without the prior steps. For many students, these concepts seem hopelessly difficult; thus, the students fail or drop out, or, on advice of others, simply avoid taking the courses because they believe them to be difficult.

All Soviet students study algebra; only half of the U.S. students do. Indeed, half of all U.S. high school graduates take no mathematics beyond the 10th grade. Calculus is taken by all Soviet high school students but by only 3 percent of U.S. students. Seven States require no high school mathematics at all.

Nearly all college-bound students in Japanese secondary schools take three natural science courses and four mathematics courses during their 3 years of high school. While SAT scores were dropping in the United States, the achievement test scores of Japanese seniors increased from 54 percent in 1964 to 71 percent in 1981--a gain the Japanese attribute to "modernization of the curriculum." By 1970, Japanese seventh graders ranked first in mathematics over students from 12 industrialized countries, including the United States, and scored first among 19 nations in science tests in both the 10- and 14-year-old age groups. In an ongoing second international competition involving 23 countries, Japan's current preliminary results show significantly increased scores over those of Japanese students in 1970 in both algebra and analysis, including calculus (News-update, Second International Mathematics Study, 1982).

It is not surprising, then, that from 1963 to 1977 industrial productivity grew 197 percent in Japan, compared with a 39 percent growth in the United States. Japan dominates the auto and steel production industries, has almost eliminated competition in consumer electronics, is the industrial leader in robotics and optical electronics, and is rapidly overtaking the United States in semiconductors, computers, and even genetic engineering.

In West Germany, there is a standard curriculum for all students through grade 10, and the only variation is in specialized science-oriented schools where each subject is studied more intensively.

It is a reflection of these differences that, on a per capita basis for the relevant age group, for every engineer graduated in the United States, the United Kingdom produces 1.1; West Germany, 1.4; Japan, 2.6; and the Soviet Union, 4.1.

PUBLIC SUPPORT FOR SCIENCE AND MATHEMATICS EDUCATION

The interim report of the National Science Board's (NSB) Commission on Precollege Education in Mathematics, Science and Technology notes that the public has not understood the importance of a firm grounding in science and mathematics for all people in a modern technological society, although there is evidence that such understanding is increasing (NSB, 1982).

For example, the 97th Congress received strong support for bills on this issue, and science education will be the subject of major legislative efforts of the 98th Congress. Administration support is indicated by the FY 1984 budgets for science education. Beyond this, the President has announced a $50 million cash program to try to produce 3,000 new mathematics and science teachers per year by providing 1-year scholarships to unemployed graduates, teachers in surplus fields, and retirees, for retraining as science and mathematics teachers. Provided in the form of block grants, the money is to be matched by the States. Some educators have expressed doubts that this retraining can be accomplished in 1 year. Nonetheless, this plan, along with the increase for science education in the NSF budget, demonstrates the political view that the public wants improvement in science and mathematics teaching.

Some States have made serious strides in pushing improved mathematics and science education. Eighteen States have enacted legislation to raise standards of eligibility for teacher education, although this move has not generally been accompanied by incentives to attract better students. Public institutions in eight western States have announced or imposed admission standard changes, or are discussing changes for the future, including tightening requirements to include more high school courses, especially in English and mathematics (Scientific Engineering Technical Manpower Comments, 1982b).

Public opinion polls show that mathematics and science education rate high among items that taxpayers are willing to support with their taxes. Mathematics ranked at the top in a Gallup survey of subjects deemed "essential" by the general public for high school students, with 97 percent of the respondents placing it in that category. Science got 83 percent, coming in fifth behind English grammar and composition, civics and government, and U.S. history (Scientific Engineering Technical Manpower Comments, 1982b).

## CONSEQUENCES OF THE TEACHER SHORTAGE

The result of shortages of qualified science and mathematics teachers already is being felt. Some schools have dropped mathematics courses, particularly advanced courses, for lack of qualified teachers. Many schools no longer offer physics. Almost all districts have had to use teachers not certified in these subjects, and the results have often been less than inspiring.

Present and projected shortages of students who are both qualified for and interested in careers in science and engineering cannot be rectified unless a higher proportion of the diminishing high school population is given the necessary preparation in high school to enter these curriculums at the college level.

The need for technical personnel in the Armed Forces is well known. This need encompasses the enlisted personnel required to maintain and use all kinds of technical equipment, as well as the engineers and scientists who develop and use sophisticated weaponry. A recent Department of the Air Force report examining scientific and engineering shortfalls (U.S., Scientific Advisory

Board, 1982) concludes: "Unless corrective action is taken, the USAF anticipates shortages of at least 10-15 percent in military personnel with the most current scientific and engineering requirements." Equally important is the fact that some military equipment is standing idle because too few enlisted men have the background in mathematics and science to be trained in the use and maintenance of the equipment.

A national study conducted in 1980 shows that only 18 percent of the U.S. adult population--varying from 4 percent for persons with less than a high school diploma to 55 percent of those with a graduate degree--is interested in and informed about scientific matters. Only a small percentage of Americans indicated that they would take an active part in controversies involving science and technology, and only one in seven has a minimal understanding of what it means to study something scientifically (NSF, 1982a & b). This leads inevitably to an electorate that may support or protest difficult policy decisions on an emotional rather than an informed basis.

This is not the first time that the United States has fallen behind in some aspect of technological development, but the consequences of this present lag, if no change is made, could be far more serious than in previous circumstances because of the rapidity of technological advancement.

There is no exaggeration in reporting that the science and mathematics teacher shortage and its consequences are at a crisis level. Some movements are afoot to alleviate that crisis; but in other areas, we do not seem to care enough to take whatever steps would be required to provide an adequate supply of well-trained, interested science and mathematics teachers and the equipment and supplies necessary for them to do their jobs well. Most school districts are unwilling to raise teacher salaries as they must be raised to attract and retain competent teachers, although most citizens in those districts probably would recognize that, in a democracy, we tend to recognize worth by the salary levels we establish for particular activities. Despite unemployment rates now in double digits, we are not taking the necessary steps to provide the educational background at the precollege level that would allow and encourage many more of our citizens to become proficient in those skills for which jobs still go begging, even during periods of high unemployment.

As we move to resolve the crisis, we might keep in mind a lesson from the Chinese. The calligraphy for their word meaning "crisis" consists of two words: "wei," meaning dangerous, and "chi," meaning opportune. Perhaps more emphasis on the opportunity that exists in this crisis might help us to alleviate the danger.

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## OPEN DISCUSSION

DR. DAVIS (Steve Davis, School of Science and Mathematics, North Carolina): We hear a lot of statistics about teachers leaving schools, particularly mathematics and science teachers being attracted by industry. I was wondering if anyone has done a comparison of whether it's necessarily industry attracting mathematics and science teachers or whether it's other careers attracting all teachers. In other words, the statistic I would be interested in is whether the percentage of science and mathematics teachers leaving for other careers is significantly higher than just teachers in general leaving for other careers.

MRS. VETTER: I don't know of any study, except the ones that have looked specifically at science and mathematics teachers going into industry, but there probably are some.

DR. ALDRIDGE (Bill Aldridge, National Science Teachers Association): We have some indirect evidence that many of the positions being filled in science and mathematics are being filled by these other teachers. So I believe that if one looks at that, it provides some indirect evidence that we are not losing those teachers to industry in the same way we are the science and mathematics teachers.

DR. SHULMAN: But what about losing them to real estate and other nontechnical jobs?

DR. STOEL (Carol Stoel, U.S. Department of Education): I think we are losing non-science and mathematics teachers because there are no jobs for them. New York City laid off 1,500 people 2 weeks ago who were not science and mathematics teachers. In Baltimore County, as I understand, they laid off some science and mathematics teachers in September.

So the problem is one of declining enrollments of young students, losing science and mathematics teachers, supplementing with underprepared teachers for the science and mathematics field, and not having the budgets to even hire part-time resource science or mathematics teachers where you might be able to use them. So there are four points there that are working almost against each other.

DR. SHULMAN: So, Steve, in response to your question, there appears not to be a national body of data unless we have something from the UCLA study.

DR. ZUCKER (Andrew A. Zucker, U.S. Department of Education): I have anecdotal evidence from one State that it is not the case that people are leaving science and mathematics any more than other areas, and there is anecdotal evidence from teachers that says the same thing. It's a little scary. In other words, it may be teaching, not just science and mathematics, that is the problem.

DR. SHULMAN: I think that, over the course of the next couple of days, we may have to address a number of times this question of: Are we singling out science and mathematics when, in fact, the problems are generic? I think that is an important observation.

DR. HECKMAN (Paul Heckman, UCLA, Study of Schooling): Again, it seems to me it's a good question. In our data in 38 schools with teachers, two things occurred. When we asked teachers why they went into teaching, they said because they liked the subject matter or they liked the notion of teaching. When we asked them if they'd do it again (and I don't have the specific percentage), about 30 percent of those people said they would not do it again--across the subject fields.

DR. SHULMAN: I often wish I had the same kind of data on dentists because I suspect that not all of them would want to do it again either. We never know what the baseline to compare these things to is, and we tend to assume that in all other fields outside of teaching, everybody is content and happy and pleased with what they're doing. Maybe that's something we have to know.

DR. STAKE (Robert Stake, University of Illinois): I'm wondering if you have some information on manpower needs in those specialties that are most predatory on the teachers of mathematics and science. Can we expect, over the next 10 years, strong recruiting efforts to get anyone who has the talents that a mathematics teacher or a science teacher has?

MRS. VETTER: We have a number of projections made by various Government agencies. They rarely agree with each other. We have some made by industry that, as has been pointed out by many other people, tend to project a shortage. Government tends to project a surplus. But I think one must always recognize that when you're looking at this, you see a shortage or a surplus depending on your vantage point. And what industry is really saying is, "I'm afraid I will not be able to hire enough of the students who come out of the top 50 percent of the class and have at least a B grade-point average." And the Government is saying, "Well, we are going to graduate 'X' number, and I don't think there will be that many jobs," forgetting that, indeed, these people don't always end up working or even wanting to work in the area in which they have a degree. If we had all the chemistry majors working in chemistry--whoever got a bachelor's degree in chemistry--we'd be overrun by chemists, to say the least. Half the women I know have degrees in chemistry. None of us are chemists.

DR. TALLEY (Wilson Talley, University of California, Davis): I have an anecdotal comment, but since it came from a senior planning official for the telephone company, I think he ought to be listened to. He says that he thinks it's just fine that the Government plans to increase the number of people qualified to teach science and mathematics in high school; that will make it easier for the telephone company to get the programmers they are going to need over the next 20 years by offering them $5,000 to $15,000 more a year than they will get as teachers.

MRS. VETTER: The important thing to note is that there is no way of projecting supply and demand. You have to do both on the basis of certain assumptions. If any of those assumptions are incorrect, your projections will turn out wrong. If they are all correct and anybody listens to them, they will turn out wrong because people then won't do what you projected they would do because they will turn out wrong.

So I don't have a great deal of faith in the projections. I do say, however, that we can constantly watch two things, and I think they are terribly important: one is the unemployment rate within a particular type of activity or industry; and the other, which is equally valid, is the starting salary levels we are offering to people. By and large, beginning salaries are a very good reflection of demand for new people.

DR. LOCKARD (Dave Lockard, Science and Mathematics Curricula Development, University of Maryland): Just an observation on a set of data that we don't seem to have. Our experience in science education, for most of us over 25 or 30 years old, is that most science teachers do not make a decision in high school or even in their freshman or sophomore year in college to become science teachers. They transfer from science majors. I think that it would be interesting to know about that, because it does affect the supply and demand.

DR. WELCH (Wayne Welch, University of Minnesota, and Principal Investigator for the 1981-82 National Assessment in Science): I'd like to offer some encouraging news. The enrollments in science courses at the high school level--the traditional courses of biology, chemistry, and physics--have increased slightly in the past 5 years--about 5 percent--even though total enrollment in science has remained relatively stable. For example, 33 percent of the seniors enroll in some kind of science course.

It seems strange to me that with enrollments remaining stable at the secondary level, that doesn't quite fit very well with the loss of teachers. At least I think we are going in the right direction. Furthermore, the declines in science scores that were typical in the 1970's seem to have leveled off, and some of these levels have increased in the latest assessment.

DR. BUCCINO (Alphonso Buccino, National Science Foundation): I feel a need to say that there were a couple of remarks that Betty made about NSF that I think really could be qualified a little, but I won't bother to do that. I do have another point about what Betty said that I think may be significant, especially for NIE, the Department of Education, and NSF.

Betty indicated and we all know that these data are incomplete, they have gaps and holes in them, and there are a lot of difficulties with them. The one chart, for example, about 1972 and 1980 enrollments that seemed to show some kind of increases...I've gotten into very, very serious arguments with people about that, because when you look at the disaggregated data, there are arguments about where those increases might be.

At any rate, the point I'd like to stress is that I hope we can take the attitude here that Betty's presentation is not the last word on the subject, with all due consideration to Betty, as far as data itself are concerned.

MRS. VETTER: That's right.

DR. BUCCINO: And one of the things that this conference might pay some attention to and suggest to us in the Government is that what we need to do is to keep an eye on this situation, perhaps give us some guidance as to the data and information collection that might be done. All of us agree that this problem, no matter what happens, is not going to disappear in the very near future. We've thought about it at NSF in 10-year terms. This teacher problem is at least a 10-year problem. So there will need to be information and monitoring over a long, long period of time.

I'd like to underscore that one of the things this conference might do is give the government--the Department of Education (mostly NCES) and NSF to some extent--some guidance on monitoring and information needs that would be helpful here.

MRS. VETTER: I think everybody in this room who has been trying to work on the data is highly grateful not only to hear you say that, Al, but to see it coming through in the budgets and such...that, indeed, NSF is now interested in the problem officially when we have known that many of you were interested in it unofficially before.

DR. SHULMAN: One of the things I hope the members of this group will keep thinking about as presentations are made is the implications of some of the terms we use, like "underqualified" or "qualified" in teaching, as an example, and what if anything we know about what those terms represent.

These are important questions. They suggest, for example, that if we treat the problems of the qualification of mathematics teachers by doubling the number of mathematics courses they take in the more advanced mathematics courses that the university offers, perhaps there will not be a magical resolution of the problems of mathematics instruction, any more than the problems of the distressing rate of infant mortality in the United States compared to other Nations is likely to be solved by adding an extra year to medical school.

I'm raising this point because I think that we have to think through how obvious some of the solutions are and whether it's a matter of simply adding more of what we're doing or thinking through some radical transformations of how it is we have been going about our business.

# NATIONAL NEEDS FOR SCIENCE AND TECHNOLOG_ LITERACY--
# THE ARMY AS A CASE STUDY

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From the Yankee inventor through Thomas Edison to Silicon Valley, the United States has provided fertile ground for innovation in technology. After World War II, almost without effort--and certainly without conscious direction--we dominated the world in introducing and incorporating new technologies into our society and in exporting them to the rest of the world. Like agricultural produce, technology appeared to be a forever renewable resource: As fast as we sold yesterday's product, tomorrow gave us a newer and better one.

Alas! For a variety of reasons, for actions taken decades ago as well as those today, we have lost that lead. Still strong, we now have to reckon with stiff international competition. Whereas 5 or 10 years ago only a few of us were concerned by early trends, today everyone has focused their attention on the symptoms of this decline. In the confusion of cause and effect, a number of studies and references indicate that, in the 1980's, we are facing or will face:

- A national shortage of scientists and engineers (S&E's);
- A loss in the "technology" race;
- Curriculum problems in primary and secondary school mathematics and science;
- Instructional and facility limitations in universities.

If true in whole or in part, these observations mean problems for our Nation. In particular, Army leadership became concerned about the Army's ability to discharge its mission in the next decade and beyond. In the fall 1981, Deputy Assistant Secretary Amoretta M. Hoeber asked the Army Science Board (ASB) to study these and other indicators, to assess their validity, and to recommend actions for the Army and other organizations that would relieve the situation. The present paper is based partly on the November 1982 "Summer Study" report of that task force (Talley, Note 1) and the November 1980 report of the President-Elect's Task Force on Science and Technology, as well as on other studies and personal observations. Thus, while many of the findings and actions proposed here are to be found in the ASB Summer Study or in the task force report, not all are, and so I must take responsibility for them.

## ARMY SCIENCE BOARD SUMMER STUDY ON SCIENCE AND ENGINEERING PERSONNEL

The Summer Study is one of the most complete assessments of the present and future S&E situations. The conclusions of the ASB Summer Study as to the Army's S&E problems are much more optimistic and positive than had been expected. Unfortunately, the problems that were identified and the solutions proposed are not as popular--in both senses of the word--as the participants thought would be the case when they began.

Despite the fact that the Army tends to be the "canary-in-the-coal-mine" with respect to its sensitivity to S&E manpower fluctuations, the fundamental conclusion was that the Army problems are manageable in the near term. This is a very positive finding, for the Army's R&D efforts and S&E requirements are a representative subset of the Department of Defense's (DOD) efforts and requirements, which, in turn, are similar to those of the rest of the Federal Government. The Army's S&E quantitative requirements--numbers of people--are not a large factor in any national shortage. Potential problems relate more to quality than to quantity of S&E's. However, the Army has cause to be concerned with the general national level of technological literacy.

It was also found that, while possible solutions to the Army's problems need more than just the Army to effect them, the Army can play a useful role in solving some parts of the larger national problem.

In what follows, the needs and actions of the Army tend to be similar to those of other elements of DOD, other Government agencies, and the private sector. One area of the Army Science Board report--the need to increase the numbers of career officers trained as S&E's--is peculiar to the Army and so will not be addressed here. Thus, this paper will discuss the most general findings and recommendations wherever possible. However, the ASB report is one of the most recent, complete analyses of the needs of a major user of scientific and technical manpower and is thus an excellent, specific case study.

## QUANTITIES OF SCIENTISTS AND ENGINEERS: SUPPLY AND DEMAND ESTIMATES

The original impetus for studying S&E manpower for the Army was a perception that there were--or would be--shortages and that the Army would be unable to compete in the labor market. Similar concerns have caused the other services and DOD to examine the situation and trends (Calhoun, Note 2; Hermann, Note 3; Rabin, Note 4; Bennett, Note 5; Seitz, Note 6). These independent studies all tend to say that there is not a general manpower problem, but that there <u>are</u> problems.

But why is there no quantitative S&E problem for the Army? Demand estimates—and to a lesser extent supply estimates—of future scientific talent are notoriously unreliable. They have proved to be so in the past; they are not likely to enjoy more accuracy in the future. Indeed, even a current census of how many physicists are now plying their trade is imprecise: Some do not wish to be counted; some degreed physicists are not working in the field; and some in the field were not originally trained in physics.

Given some figure for the present pool of a particular type of scientist, however, actuarial estimates give reasonable numbers for the declines due to deaths, retirements, and job switching. This third factor is sharply affected by external economics and/or scientific breakthroughs in particular fields.

Complicating the picture is the fact that the decision to preserve the option of going into a career in the hard sciences or engineering is best made at the junior year of high school—grade 11. The typical source of information about <u>job</u> opportunities for these youngsters is television and the print media. Because "news" is more often "bad news," the typical story about jobs for scientists and engineers is invariably about unemployment. There will be an occasional story about high salaries, but only because a "critical shortage of new blood is about to cost the United States its leadership in field 'x'." Thus, because of the 6- to 10-year "processing" time, we tend to have cycles in the technical manpower picture. At its worst, the oversupply in scientists and engineers result in unemployment/underemployment approaching that of the general population. Because the "normal" unemployment rate for technical personnel is an order of magnitude lower than that for the general population, the periods when the technically trained lose their employability edge occasion widespread publicity.

The bottom line on any set of projections is whether the end result is predicted to be a matching of jobs to people or a mismatch in one direction or the other. Because such "net" predictions tend to be reverse prophecies (that is, they are the opposite of "self-fulfilling" prophecies), the important consideration in evaluating the validity of these predictions may well be the institutional home of the people making the projections. For example:

- Teams composed of those representing industry tend to predict future shortfalls. This produces an attraction of students into those fields and, eventually, a glut, and industry finds itself in a buyer's market for talent.

- Professional societies, especially those that are protective of their members' careers, can be counted on to predict miserable times ahead. The "golden age" is past: jobs won't be available, industrial and Federal research budgets are down, and so on. If the audience of young people believed these dire forecasts and if there were no other influences, there would be a diminution of new entrants into the pipeline, some already in would drop out, and the end result would be an eventual seller's market.

- Academicians face a dilemma in that their institutions need grist for their academic mills, but their graduates need jobs. Breaks from an understandable paralysis of indecision generally result in well-tempered, middle-of-the-road projections. However, these usually are projections that tend to run against the stronger of the two currents above.

Despite these problems, heroic efforts on the part of people like Betty Vetter have produced useful quantitative estimates of the current supply of scientists in the United States, with the variations in these estimates being due mostly to differences in data bases. For instance, to be included in the National Science Foundation's (NSF) total science and engineering pool, an individual must possess two or more of the following qualifications: (1) highest degree is in science or engineering; (2) current or most recent employment is (was) in a science or engineering job; and (3) self-identification is as a scientist or engineer. Qualified scientists and engineers employed in non-S&E jobs who report their non-S&E field are not counted in the survey. The size of the pool, as reported by the NSF, is 2.741 million. Considering that 5.58 million persons have earned one or more degrees in science or engineering since 1948, one could conclude that S&E shares with law training the fact that 50 percent of those trained in the field do not practice the profession!

Of the DOD employment of S&E's, the Army can be considered "average" or "representative" of three services. While the Army has fewer uniformed S&E's than the Air Force, it has more civilians. Thus, it is not surprising that the recent ASB Summer Study agrees in general with the conclusion of other DOD studies in this area. Namely: Despite occasional regional mismatches of supply and demand in some fields, the problems of the Army (and of others in DOD) in recruiting and retaining quality S&E's are only secondarily related to these shortages. While exceptions can be found, particularly for upper level S&E vacancies left from the massive retirements and resignations in 1979, neither available aggregate statistics nor interviews with Army R&D managers support a conclusion that the Army is unable to attract and retain adequate numbers of S&E's. This is particularly true at the "working level"--GS-7 to GS-13. Since October 1980, the size of the Army S&E workforce has grown by approximately 7 percent, from 27,500 to 29,600. The Army S&E voluntary loss rate, which in the 5-year period 1976 through 1981 ranged from 1-1/2 percent to 2-1/2 percent, compares favorably with the Department of Defense as a whole and with comparable industry statistics.

In the event of a real shortage, and certainly with respect to hiring quality S&E's, the Army is at a competitive disadvantage with the private sector for several reasons: The Army is unable to pay for expenses incurred in an employment interview; the Army takes a considerable amount of time to make a job offer; and Army starting salaries are lower. Although the Army may hire directly, scientists must appear on an Office of Personnel Management register before the Army can even consider them for employment. This is particularly unfortunate in the case of computer scientists, for whom the national shortage is as serious as it is for engineers. In short, the Government personnel system does not accommodate to the needs of S&E employees--they are a minority much more strongly affected by market forces than the majority of Government employers.

Overall, however, the Army has no "numbers" problem because the Army employs only about 1.2 percent of S&E's, its skill mix lags the current national distribution (so the Army does not compete for the newest, thus smallest, components of the pool), and it usually does not attempt to compete against industry for the very top S&E's.

That ends the good news.

REDUCING DEMAND

The fact that there does not appear to be a quantitative problem with S&E's should not lead to a false sense of security, since there is no objective basis for concluding that the quality of the S&E's is adequate to meet Army requirements. Each year, some 150 to 200 S&E's voluntarily leave the Army work force at the GS-12 level. This fact may not be disturbing in itself. If, however, these losses comprise the higher quality from the journeyman level, as many managers seem to believe, the numbers become alarming. There are parallel losses in other DOD services (Rabin, Note 4) and in non-DOD agencies.

There is a distinct lack of objective indicators. Anecdotal comments, ranging from "quality has never been better" to "none of them are competent," can be found to support any claim for current new hire quality. Similarly, quality assessments of existing S&E's are subjective and diverse. Unless the Government commits itself to making objective assessments of staff quality, which can be monitored for trends, it will never be in any better position to confidently assess the quality of its S&E's.

Finally, the Army and the other services are shifting toward ever higher technologies. It makes little sense to spend millions on sophisticated hardware and software if the people--not only officers but enlisted personnel as well--needed to maintain, operate, and repair the systems are unavailable. It may be the question of national technological literacy that is the most critical to the Army as it strives to discharge its mission.

There are several ways to attack mismatches of supply and demand. One major thrust to reduce unnecessary demand is to review and rationalize the manner in which defense contractors--a major sector of all S&E employers--use such people. DOD is captive to a procurement process that wastes S&E talent in the development of new systems and produces finished items that demand high skill levels of the users.

The ASB Summer Study points out that multiple contractor competitions may result in largely wasted effort by many of the best S&E's of the losers. This may amount to the loss of tens of thousands of valuable person-years. The waste is particularly evident when all contractors are technically qualified, DOD specifies the design point details, and the competition seeks only to establish the lowest credible cost estimates. Here, the low bid may result from minimum factory costs, yet the most creative and competent S&E's of the losing contractor(s) waste their time producing separate designs, all of which meet military specifications.

Many DOD contracts specify complete system integration to allow minimizing initial acquisition cost. Thus they make no provision, provide no budget, and give no competitive credit for designs having minimum times and costs for system upgrades to overcome obsolescence. This can result in the use of numerous contractor S&E person-years for major redesigns or in completely new programs to correct a system for obsolescence of some of its key elements, despite the fact that other elements may not be obsolete for many years.

There is as yet too little appreciation of the advantages of designing and fielding "user-friendly" systems, that is, systems that require little training to use and that are easy to maintain, operate, and repair. Not only do such systems enhance operational efficiency, but they keep the requirements on the intelligence and educational background of operating personnel to reasonable levels. This same consideration applies to civilian products, but the market tends to favor user-friendly products--simple survival will eventually produce the easiest-to-use products.

The tendency to look only at front-end costs is not restricted to the DOD. The sewage treatment plant program of the U.S. Environmental Protection Agency (EPA) is a particularly apt example, because of its eventual impact on primary and secondary education! The EPA pays 80 percent of the capital costs: the State and local governments pay the rest. The problem is that the $60 billion is spent primarily as a public works program. The technology installed is that of the 1930's. Because of this, the operation and maintenance costs over the 30-year life of these structures will be as much as five times that required of plants using the latest technologies. These facilities require an unnecessarily high level of technical competence for their operators. And the local government must pay the operating costs with tax dollars that could have gone for primary and secondary school support! Thus we have an example of a lack of "technological literacy" producing a situation that is not only costly but tends to continue technological illiteracy.

INCREASING SUPPLY

There are several aspects to increasing the supply of S&E's. One has to do with increasing the quantity of S&E's, another with maintaining their quality. Yet another touches the matter of upgrading and increasing the pool of high school graduates capable of (and interested in) careers in science and engineering--and thereby of raising the general level of our national technological literacy. These topics are difficult to separate.

Training Scientists and Engineers

No one has been able to establish an "ideal" student/faculty ratio, nor has anyone been able to ascertain the maximum ratio beyond which the quality of education declines. However, based on authoritative statistics of the past 15 years, it is clear that neither the number of faculty nor the number of new Ph.D.'s (the pool from which faculty are drawn) is growing as fast as undergraduate engineering enrollment.

In particular, the overall student/faculty ratio in United States engineering schools has increased by nearly 50 percent since 1974 and is continuing to increase. Furthermore, the number of new engineering Ph.D.'s has been falling since 1972, with most of this reduction due to declining numbers of United States citizens earning Ph.D.'s. As a result, the outlook for the next decade is still fewer engineers qualified to fill faculty positions, with the likely outcome being further increases in the student/faculty ratio. It is certain that if these trends continue, the quality of undergraduate education for engineers will at some point deteriorate to an unacceptable level.

Another problem is the ability of universities to maintain first-rate research facilities, as distinct from maintaining first-rate teaching equipment. A decade or two ago, the major research universities had facilities that matched the best to be found in industry or in Government. No longer. Deferment of replacing equipment has reduced the ability of some schools to train S&E's in the forefronts of certain felds. Compounding the problem is the fact that new equipment is far more expensive than that it replaces--far beyond increases attributable to inflation--and becomes obsolete even more rapidly. This would indicate that the traditional methods of rebuilding these assets (Government or foundation grants, say) are not likely to work.

## Increasing the High School Graduate Pool

Great concern has been mounting within the past few years over the lack of scientific and technological literacy, i.e., understanding technology and its potential, of United States high school graduates. Many factors are responsible for this dismal condition. Very few secondary students take any mathematics or science courses beyond 10th grade. This is in marked contrast to countries such as Japan, Germany, and the Soviet Union, which provide rigorous training in mathematics and science.* In many cases, students take only the minimum amount of credit hours in these subjects to fulfill the high school graduation requirements. Because of these minimum standards, a small number of students elect to take advanced mathematics, statistics, physics, chemistry, or calculus. Honors or advanced courses are available at some schools, but they are for those few who have taken the prerequisites and who want to take those courses. Only about one-sixth of all secondary school students currently take junior and senior courses in mathematics and science.

The common perception is that this will eventually reduce the numbers of people studying for bachelor's, master's, and doctorate degrees in science and engineering. There is little evidence to support this contention. On the contrary, as engineers make up 6 to 10 percent of the college population, the pool of high school graduates that could major in S&E is still far larger than the number who do major in S&E. Fluctuations in the number of S&E's in college depend more on high school students' perceptions of career opportunities than on the quality of elementary and secondary mathematics and science education.

## Increasing the General Technological Literacy

The more serious problem is related to the ability of our increasingly technological society to function smoothly if our citizens do not become more technologically literate. While there can develop the general problem of an electorate having to decide between two technological options without fully understanding either, the military has more specific problems.

It has been suggested by Dr. Russ O'Neal that:

> "We won World War I because our troops could repair bicycles; and we won World War II because our troops could repair trucks; but we could lose a World War III unless our troops can operate and maintain computers!"

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*For example, Japan has a national guideline that 25 percent of instructional time in grades 7 through 9 be devoted to mathematics and science. The Soviet Union has national elementary and secondary curriculums in mathematics and science, and Germany has a standard curriculum for all students. In contrast, in the United States, most students take no mathematics or science beyond grade 10, only one-third of the 17,000 school districts require more than 1 year of mathematics or science to graduate, and classroom laboratory facilities and equipment are obsolete and/or unsuitable for modern technical training.

Even if this is only partly true, it illustrates the fact that the Army should be very interested in the general population's level of technological competence. "High technology" is a relative term. The typical U.S.S.R. inductee must be taught to drive a truck, while his United States counterpart begins service with that skill. This operational advantage should remain with the United States even to the year 2000, if the average American retains a level of technological literacy comparable to that he or she has today.

Unfortunately, the present "educational system" in the United States primary and secondary schools works to slow the rate of rise in its graduates' technological literacy. Consider: Of those high school graduates who have little interest in or aptitude for the hard sciences, some will go on to college. Not surprisingly, few of these people will take advanced mathematics, statistics, physics, or chemistry. Given these circumstances, their career choices are constrained. Among careers open to them is "education," and some will select that field. Upon graduation from college, they become accredited primary and secondary teachers. While some accredited teachers are competent to teach science and mathematics, they are in short supply.* Indeed, those who can teach these topics are eagerly sought by industry. As it's rare for competent mathematics and science teachers to receive premium pay, it takes dedication to resist industry. The odds then tend to favor the situation in which the next generation is exposed to mathematics and science by people uncomfortable with the topics. Students taught subjects by teachers who are incompetent in those areas are unlikely to explore the topics further. And so the cycle repeats.

## SOLUTIONS: SHORT- AND LONG-TERM

As present national problems and trends were a long time in building, it is not likely that the solutions will be easy to apply nor quick to take effect. Further, no one element of our society can provide all the answers by itself--certainly not, for example, the Army. And as an illustration, the Army can remedy only a few of its problems. But there are actions that can be taken by the Army, by the DOD, by the Government, and by the private sector that can have immediate impact. And there are other actions that can lead to the long-term resolution of our difficulties. Both short-term and long-term solutions should be attempted.

The first actions should be those that reduce the demand for scientists and engineers. As an example, DOD acquisition procedures that presently may exacerbate contract needs for S&E's can be largely corrected by expediting

*A recent survey conducted by the National Science Teachers Association found that, in the worst region--the Pacific States area--84 percent of newly-employed science and mathematics high school teachers were unqualified to teach in these areas. Paul Hurd, emeritus professor at Stanford, reported at a May 1982 conference of the American Association for the Advancement of Science that, nationwide, of the teachers employed by high schools to teach mathematics or a science for 1981-82, 50 percent were unqualified and were teaching with emergency certificates.

implementation of those (Deputy Secretary of Defense) Carlucci Initiatives related to procurement efficiency. In particular, more clearly defined selection criteria, including identification of disqualifiers (such as overload, lack of credible capacity, lack of credible ability to build-up, etc.) could discourage potential losers from entering competitions, thereby probably reducing the number of companies that waste S&E efforts by 40 to 60 percent.

Over the longer term, if systems were engineered to permit product improvement once fielded, there would be less frequent need for massive R&D efforts to develop totally new systems. (An added benefit is that the cost of defense systems probably would then decline.)

The use of computers for various types of engineering and scientific work can substantially reduce the total S&E hours required for a program, particularly during large program buildups requiring numerous new hires, and thus also reduce the need for more S&E's. However, many companies, particularly at the second and third tier subcontract levels, will need Government help to defray the cost of computer intensive systems.

The second tier of actions should be to provide new S&E's for the Nation and to upgrade the skills and talents of existing S&E's. There are several such actions. The first, if adopted, could have the same sort of impact on S&E education as did Sputnik.

Defense contractors have utilized the approximately 50 percent tax write-off to tender support to universities. This support is now needed, especially in those areas of technology vital to national security.

The simple expedient of allowing 100 percent recovery of university-related expenditures by contractors on defense contracts would achieve the desired results. Examples of such expenditures would include the following: fellowships; purchase of equipment; refurbishing or building facilities for key technologies; unrestricted funds to aid faculty recruitment and retention; participation in nontask specific activities such as industrial liaison, VLSI, and CAD university/industry consortia; and employee education expenses currently disallowed. Each contractor should be allowed to structure his own program, guided by his enlightened self-interest, and should have the freedom to select universities of his own choice. The amount of expenditures can be controlled by establishing a ceiling, applied uniformly, as a percentage of the contractor's DOD sales.

The DOD need not work only through its contractors. It can also move directly to bolster the ability of universities to provide competent S&E's by, for example, expanding scholarships and fellowships targeted at fields of interest to the DOD or continuing and expanding the practice of employing faculty as consultants. And in areas of particular concern to the DOD, areas that are relatively neglected by the rest of our Nation, consideration should be given to establishing and supporting "centers of expertise" at universities. For example, the Army supports a Center for Mathematical Research at the University of Wisconsin-Madison and has begun to set up three Centers of Air Lift Technology. Even in areas that are currently "hot" in academia, elements of interest to the DOD sometimes tend to be underexploited. For example, in biotechnology, quick vaccine production and detoxification agents may never be developed through market forces.

The term "center of expertise" is used to span the spectrum of ways to gather together critical masses of people, as well as convey an intention of stability in the funding pattern. "Boom and bust" funding must be avoided. With sufficient duration, support in a technology/science area creates a pool of talent. The talent may be the workers at the center or its graduates, but the people are an implicit resource, as consultants or as prospective employees. Thus, the center would produce not only data, but also the personnel necessary to make further advances in the field.

This center of expertise--in essence, the academic equivalent of the "warm production line"--would be maintained to assure a stream of products/talent in a vital area. Either these fields or those where progress is painfully slow may require many years of DOD support. But even for these, an end must be anticipated even as support begins. Thus, a general rule in establishing centers should be the expectation of an eventual end to sole DOD support, and periodic reviews (say, every 3 years) should be made to determine whether continued support is warranted.

No one is likely to object to the above center of expertise concept. Let me now suggest a more drastic solution: That the DOD and comparable high technology institutions must move into an activity once solely the province of American universities--the education of graduate S&E's in the conduct of research.

Not only are the scientists and engineers of such agencies as the Department of Defense, the Department of Energy (DOE), the National Aeronautics and Space Administration (NASA), and others frequently local or national experts in their areas of technical competence, but the installations of such agencies -- particularly the laboratories -- may have research equipment unavailable to local colleges and universities. Several agencies have programs for internal personnel upgrading and collaboration with local schools. Such programs should be extended and new ones begun aimed at the utilization of Government personnel (as formal instructors and research advisors) and Government facilities (as research tools) to produce master's and perhaps doctoral graduates. As those elements that contribute to successful programs emerge, other elements of the technical community should adopt or adapt them for their own programs.

Models for these programs already exist. For example, there are 1,200 evening school students at The Johns Hopkins University who are taught at the Applied Physics Laboratory (APL) by instructors who are usually APL employees exceptionally qualified in their areas. About 20 percent of the students are also APL employees. The curriculums lead to master's degrees.

At the Department of Energy's (DOE) Lawrence Livermore National Laboratory, over 100 graduate students are working for master's and doctorate degrees in the Department of Applied Science (DAS), a 19-year-old department in the College of Engineering of the University of California, Davis. Davis and Livermore are 70 air-miles apart! Students not only have access to some $450 million of research equipment, but can also receive all their formal coursework at Livermore from instructors chosen from among the 900 Ph.D.'s working at the Livermore lab.

An excellent case can be made for allowing, if not requiring, "real world" experience as graduate students earn their degrees. As an example, the Fannie and John Hertz Foundation encourages its fellows to accept part-time and summer employment with cooperating institutions such as the Livermore National Laboratory, the Los Alamos National Scientific Laboratory, the Charles Stark Draper Laboratory, the Princeton Fusion Research Center, and others. Other efforts at involving graduate students with "real" research include Livermore's Navy-sponsored S-1 "supercomputer" program, which routinely uses MIT, Carnegie-Mellon, and Stanford computer science graduate students as part-time laboratory employees. The Ph.D.'s produced by these programs have an understanding of the frustrations and rewards of a career in research seldom acquired by their peers who have never ventured outside academe.

The suggestion that universities give up the physical propinquity of their graduate students is difficult to sell, but it pales in comparison to the final recommendation of this paper: that the science and mathematics education in primary and secondary schools is too important to be left to professional educators who are technologically illiterate.

The geographical dispersion of Government laboratories and installations offers opportunities for Government S&E's to alleviate the national problem of technological literacy in elementary and secondary mathematics and science through a variety of mechanisms. The Government could, for example: provide release time to Government scientists and engineers to teach in public schools, either for whole semesters or through team teaching approaches; provide equipment and laboratory facilities to local schools; initiate enrichment programs, during the school year and/or the summer, to motivate students to pursue scientific careers; and support the work of existing commissions that are directing their attention to mathematics, science, and technology education (e.g., the National Science Board, the National Commission on Excellence in Education).

About a decade ago, the NASA-Ames Research Center began outreach programs that have involved junior and senior high school students and teachers in the physical and biological sciences. The programs include undergraduate and graduate students and their faculty, and they range geographically from local schools to Midwestern universities. Senior researchers at Ames have conducted formal courses at nearby Stanford University.

Other national technology-oriented organizations with local operations, for example, the local telephone company or the local power utility, could be induced to assist the Government. Also, efforts of industry and professional organizations to prepare material to help motivate student interest in science and engineering should be used. For example, the American Society of Mechanical Engineers, with the help of Bendix, Bell Labs, Proctor & Gamble, and Digital Equipment Corporation, is developing a 27-minute film targeted at junior high school students that demonstrates the rewards and benefits of being an engineer.* Finally, the provision of part-time and summer jobs for skilled mathematics and science teachers should be an obligation of all high-tech firms in an area. Ultimately, teachers' compensation should follow market forces, rather than seniority or other artificial rules.

Let me state explicitly that "Government S&E's" and "Government facilities" include the Department of Defense. The DOD has had a long history of cooperative association with education in our country. While it may be currently popular to rail against Defense or Energy, such agencies fulfill needed functions. They should be utilized as resources where they can contribute, not be ostracized.

State and local certification requirements for teachers may make it difficult for technically competent but amateur educators to gain immediate access to the schools. Provisional or temporary certificates may be granted for short-term teaching opportunities. The purpose of these bureaucratic barriers should be to protect students from unqualified teachers, not to protect a system from competition. If reform from within--cooperation of State and local school authorities with those concerned with solving our S&E problems--does not occur, the revolution from without will surely follow. The penalties--the lost opportunities to provide first-rate exposure to science and mathematics--are just too great to be permitted to continue.

*An obvious improvement would be the production of 2-minute spots for use on television to achieve the same result.

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## OPEN DISCUSSION

DR. ALDRIDGE: Let me repeat a comment which Dr. Talley made. He said that what we needed to be concerned about was to improve the technological literacy of the population, and that our problems were not principally to better prepare scientists and engineers. I want to raise a question: We all know that the curriculums of the 1960's in the secondary schools were designed principally to prepare scientists and engineers. We also have firm evidence that those curriculums are inappropriate to the present student body, that is, for the majority of them.

Our concern is this: In all the Federal programs, in all the bills that have been introduced in Congress, none has proposed large national efforts at redevelopment of the curricula. Instead, they want to provide all 17,000 school districts with an opportunity to reinvent the wheel in all 17,000 places. I'd like to get some comment about that.

DR. TALLEY: You are right. If the population had a higher level of technological literacy, we would not have a problem with finding qualified primary and secondary mathematics and science teachers. Let me be candid. Right now, students get turned off to mathematics or science in high school. And some of these students go on to college. So what fields can they go into where they don't have to have mathematics or science? There are a number. One of them is education. So they go through and they become teachers. And they are expected—they are forced—to teach mathematics or science, a field in which they never took any more courses in college if they could get away with it. It was distasteful to them when they were kids themselves. And they are exceptional if they can avoid communicating the distaste they feel to the next generation, and so the cycle repeats itself.

What I am proposing is that you get the people who know how to teach to teach—"Everyone ought to be a scientist and engineer like me."

I believe that Betty (Vetter) mentioned the difference in teaching between the United States and some other countries...where we face our kids with abstractions, some of which were those high-powered mathematics and introductory science courses that were generated post-Sputnik. I would assume that if you had available to you someone very competent and enthusiastic, you would not scare the kids off.

I just don't know that we need to develop new curriculums, which is the answer to your question, but I wanted to get my comments in first.

MRS. VETTER: I think we are in desperate need of some new curriculums. And I don't think we necessarily would be if we had a generation of science and mathematics teachers who had grown up with all of the competencies that we would all hope our science and mathematics teachers have. But the fact is that that is not what we have and that is not what we are getting. And at the moment, I don't see any prospect that we will be getting it, which tells me that what we need, among other things, are some better directions.

I have been reading some things about the way textbooks are selected, which probably would come as no surprise to many of you. But a lot of what I have been reading on how public schools' books are selected, certainly those in science and mathematics, scares the daylights out of me. I would like to see some good curriculum development done on a national scale in a national laboratory--trying it out first, but coming up with some good information that would then get into the school system, not the way current textbooks are chosen.

DR. SHULMAN: I would like to make two comments on those comments, and then toss it back to the floor. One comment is that I am sure you have been watching the beginnings of the reports of the many secondary education commissions, which range from the Carnegie's to the National Academy of Education's to...I think there were 32 at last count.

There seems to be an interesting confluence of perspectives coming out of these commissions on secondary education, which will be very consistent with what Betty Vetter seemed to be arguing for; namely, that the proportion of the high school curriculum that is elective, and therefore affords the opportunity for students to avoid taking what Betty called the academic courses, should be sharply reduced, and that there ought to be much more stringent requirements for everyone who goes through high school. And you are seeing this now reflected in recommended changes in State requirements for high school graduation.

These are very interesting recommendations, but from a curricular perspective there is something rather magical about them because there really are no curriculums for those students in physics or chemistry or algebra II who have been avoiding those courses for the last 20 years. If there is anything we know for sure, it is simply that using the same curriculums they have been avoiding is probably not going to be the answer.

DR. TALLEY: This is a question for tomorrow. We will have a person from the Argonne National Laboratory where they have been doing this sort of thing. My question after that presentation is: Are you producing the next generation of scientists and engineers or just trying to raise the general level of technological literacy? If it's the latter, have you had any problem figuring out the curriculums to do it? And that is tomorrow's question.

DR. SHULMAN: I'll make one other observation about curriculum, and that is the potential danger in treating curriculum as something that we do nationally that we then finish, polish, sand down, package, and send out. We might begin to think about curriculum-making and curriculum development as something that ought to involve tens of thousands of teachers across the country, on the grounds that making new curriculums or revising old ones, in collaboration with scholars of various disciplines and with educationists of various sorts, is likely to turn out to be one of the most powerful forms of teacher education and teacher development that we have ever seen. Speak to the teachers who were involved in some of those NDDA and NSF institutes in the 1960's. And don't just ask them about how good the units they developed were: ask them what kinds of changes were wrought in them as understanders of science and mathematics and as teachers thereof.

DR. RAIZEN (Senta Raizen, National Academy of Sciences): I really would like to associate myself with all of the remarks here about the desirability of a technologically educated citizenry. But I do have a difficulty, and I think it is a previous question to the curriculum question. I would like either Dr. Talley or anyone here to tell me what the functional definition of a technologically literate person is. Because until we can define that, we don't know what to put into the curriculum, no matter how we get at it.

DR. TALLEY: I think a technologically literate person is one who would recognize that a new technology is introduced to solve a problem; that there is no such thing as an absolutely benign process, technology, or gadget; and that he or she, as a consumer or a voter or a taxpayer or the like, is going to have to choose among options, none of which is perfect.

The scientific method is really a neat method for deciding whether or not you are being conned. I could not think of a polite way of stating it. I don't think it has to do with having a certain number of courses in trig or calculus or chemistry--just an appreciation that the universe does not run by magic.

DR. HICKS (Laurabeth Hicks, U.S. Department of Education): I can remember in the 1950's when large amounts of funds flowed into programs to prepare school counselors to identify elementary and high school students interested in and having the potential to develop high level skills in mathematics and science. Are there data to indicate what impact...what success...the counselors had in these programs?

I would also like to know what should be or will be the role of the counselor? Do the counselors need retraining in order to help the schools and students with the mathematics and science crisis?

DR. SHULMAN: I suspect you know that before teachers are laid off, they lay off all the counselors. Counselors are generally the first group to go. And I think what you are suggesting is an interesting kind of researchable question, which is: To what extent are we in error to assume that those people who are not in classrooms are not playing an important educational role with respect to science and mathematics education?

DR. HECKMAN (Paul Heckman, University of California, Los Angeles): I would like to reinforce the notion that curriculum is a fundamental issue here. It seems to me that one has to raise the question of technological literacy in the light of what is a general education for children and youth? When we speak before a group of art educators, one of the things they ask for is an increase in time for the arts. If you go before a group of science persons, they obviously advocate more science.

It seems to me that we are going to have to raise this question in light of what happens at a school, rather than averages. And it seems to me in our study of schooling at UCLA, for example, even though there were averages, there were some very severe school-to-school variations--something like 3 percent of art courses in one school versus 20 percent allocated courses in another.

My other statement has to do with requiring more courses. I guess the question I always have--and, again, I think it relates to Dr. Shulman's statement: Is more better? When we looked at our data, one of the things that came across loud and clear was that the predominant method that was used by teachers in a thousand classrooms was simply lecture with students sitting and listening. I'm not sure students ought to sit in mathematics classes listening more for a longer period of time. Therefore, it seems to me that the call for addressing the curriculum is very, very important if we are going to move beyond just teachers teaching. Incidentally, one of our colleagues looked at a study done in 1910, and again the predominant mode of instruction was lecturing to a large group while they sat and listened.

DR. SHULMAN: Mary Anne Amarel, who is a distinguished educational researcher, did a set of intensive case studies on high schools. One was the Bronx High School of Science, and another was a high school in New York City whose name I don't recall but whose focus was the graphic arts. Her conclusion was that the quality of science teaching was really outstanding in the high school for the graphic arts and the quality of teaching the humanities was really outstanding in the Bronx High School of Science. But the quality of teaching in the areas where they were specialized was rather dismal because they did so much more telling and they tried to pack and compact stuff so much.

I'm simply echoing your observation, which is not to say that more cannot be better, but that we've got to be very careful about the mix.

DR. LAPP (Doug Lapp, Science Coordinator, Fairfax County, Virginia): I guess the main distinction of the Fairfax County School District is that it is the 10th largest school district in the Nation and probably has the highest median income. So in that respect, I think it is useful to look at what are the capabilities of such a district in curriculum development, because it is often said this is the province of the States or the province of the counties or the local jurisdictions.

I would like to say that we just don't find it possible, and I don't think we ever will, to assemble the expertise to develop curriculums of the quality that is required in science and technology and keep those current. A very high standard was established for science curriculums by the curriculum projects in the 1950's and 1960's, and some of them were targeted toward science and engineering specialists. I think we all recognize that. And we are looking for something to follow that up, and it's not there.

Local districts can assume control and maintain control over the curriculum by using an eclectic approach--by combining elements developed from various projects into things that fit local situations, local capabilities, and facilities. But in no way can they develop curriculums without academic support from universities, et cetera. And we have just not been able to assemble that.

The other thing that I would like to add is I do support very much Dr. Talley's suggestions of getting industry and Government labs involved in science and mathematics education and support. We have noticed an increase in this, what with the clarion calls in the press that our science education is flagging. And I have had professional associations and Government laboratories (of which there are many in the Washington area) come to our aid. But when they find out that a scientist who has great intentions would be required to come in and teach five identical presentations in one day, and possibly take a day to plan that and several days to follow up, their interest wanes. They were thinking maybe of one large presentation which would change the whole face of education for that year.

It's a wonderful idea, and I think we should support it in every way and provide incentives and recognition, but it cannot really affect day-to-day teaching. The most it can probably do is raise the morale of science teachers to be more similar to what you find in Europe among secondary science teachers. That is, they have a great identification with the academic science community...industrial science community...and they feel that they are in contact. And that is what is needed more, perhaps, than anything else.

Also, for as long as I can remember, we have had a drain-off of talent. When you had National Science Foundation institutes for teachers, it tended to funnel them off into other positions the more expert they became. However, there was a time when teaching was improved, and the institutes provided important standards of quality in teaching. Many teachers did stay, and they provided a bootstrapping effect on the other teachers.

DR. TALLEY: I am going to be very interested to hear what Argonne has done because I know that the NASA Ames facility, the NASA Lewis facility, and every Army laboratory that I have visited that has been near a population center, have programs in which they not only bring students and teachers into the labs but their people go out to schools. I recognize the problem you state, and yet somehow these people seem to be resolving them.

DR. ROBERTS (Linda Roberts, U.S. Department of Education): Last year, I had an opportunity to do a series of case studies of school districts moving ahead in applications of computer technology in education. And, like you, I was able to see many striking examples of districts who went into the community and used the resources that were there.

My question to you, though, is: What does a community, that has no resources like the Argonne National Laboratory, do? I raise that because we have many, many school districts in this country that are primarily in non-high-tech areas.

DR. TALLEY: "High tech" is a relative term. Thanks to the 435 congressmen, each representing a district, we seem to have spread throughout the Nation Government facilities of varying stripes and levels. I think it has been well brought out that what we are not after is to train that 1 percent, but to raise the average understanding of our citizenry. And I suspect that you are going to find that while you do not have an Argonne in every school district, you have a Corps of Engineers laboratory or Department of Agriculture experimental station or something. If you don't, then at least one of those 435 congressmen was not doing his or her job.

DR. SABAR (Naama Sabar, Tel Aviv University, Israel): I really want to expand a little bit on what Lee (Shulman) and some others have referred to as the problems of the new curriculums and the role of the teacher in that sense. I think the problems of the new curriculums, so-called, are not so much in creating them as in implementing them. We really never got to the point where we saw in reality what we had hoped to see. So with this kind of disappointment that has prevailed in the Western world, we observe now a new trend which is called "school-based curriculum." It is not meant for the teachers to reinvent new excellent curriculums, but just meant to be active participants in making learning materials.

This (school-based curriculum) has been tried successfully in England, in Australia, and even in Israel. And the Rand Corporation report about change in staff development came out with very strong recommendations for taking teachers as active partners in curriculum development, mainly in revising, adapting, and changing curriculum for their own needs.

I would therefore encourage the NSF in their new inservice courses to activate teachers as equal partners, rather than imposing what is known already in the curriculum.

# SESSION III
# SCIENCE EDUCATION

## RESEARCH IN SCIENCE EDUCATION: REVIEW AND RECOMMENDATIONS

Wayne Welch, Professor of Educational Psychology and
Director of the Research and Evaluation Center
University of Minnesota

The past decade has been a difficult time for science education. Declining test scores, shortages of qualified teachers, low enrollments, reduced confidence in science, and loss of Federal support are some of the problems that have plagued the discipline. Science teaching has struggled to retain its position in the school curriculum. Some have claimed a national crisis exists (Press, 1982; Opel, 1982; Yager et al., 1982).

In recent months, however, a number of activities have occurred that indicate a renewed interest in the field. The budget for science education in the National Science Foundation (NSF) was doubled in fiscal 1983. The National Academy of Science (NAS) held a meeting last fall to consider precollege education in science that was attended by more than 600 business, political, and educational leaders. The National Science Board (NSB) has established a commission on precollege education in mathematics, science, and technology, and professional societies such as the American Association for the Advancement of Science (AAAS) and the National Science Teachers Association (NSTA) have stepped up their efforts to draw attention to the problems. A number of bills have been introduced in the Congress that are designed to improve our Nation's capacity to improve science teaching.

This renewed interest in science education is supported by the results of the 1981-82 National Assessment of Educational Progress (NAEP) (Welch & Anderson, 1982). Enrollment in traditional science courses has increased, and at three age levels (9-, 13-, and 17-year-olds), the declines in science achievement noted for a decade have leveled off. At age 9, there was a slight increase.

Because of growing public attention, the National Institute of Education (NIE) was asked to develop a research agenda for science and mathematics education. What research questions are most pressing? How can we improve science teaching? What do we presently know and what should we find out? These questions were posed to me at a meeting with NIE staff and are the basis for the discussion that follows--in essence, a needs assessment of research in science education.

I struggled for some time with two concerns: How can I avoid advocating my own research interests? What determines a needed area of research?

I decided to address the first concern by considering the total domain of science education and reviewing previous work in this context. The second question was more problematic. A need could grow out of a personal interest area, a discrepancy between a wish and a have, an intriguing question, a National priority, or a combination of these. The needs definition that evolved has three elements: (1) gaps in our knowledge in important areas; (2) high national priority; and, most importantly, (3) limited prior work in promising areas.

I do not think we should cover ground that is well-trodden, but neither should we chase rainbows. I tried to develop my research agenda in that middle zone between the known and the unknown.

I use three procedures to conduct this needs assessment. First, I describe the domain of science education. Second, I examine several recent meta-analyses and research reviews in light of the proposed domain, and, based on the research results and the extent of research in a given area, I identify those areas that seem most promising for future research. Third, I compare these areas with other assessments of research priorities and recommend five specific research questions.

## A SUGGESTED DOMAIN FOR SCIENCE EDUCATION

When considering a topic as broad as science education, one must outline that topic in some detail in order to speak clearly of it. It is also essential to define the domain to ensure that important components are not overlooked.

My view of science education has been expressed elsewhere; first in an NIE-NARST committee report (Yager, 1978), and more recently in my work with Project Synthesis (Harms & Yager, 1981; Welch et al., 1981). This view is based on an evaluation model suggested by Stake (1979) and modified for science education. What follows is an extension of that earlier work.

The domain of science education can be viewed as comprising three main components: context, transactions, and outcomes. The <u>contextual</u> component refers to the set of conditions existing prior to the exposure to learning. It includes such things as curriculum materials, trained teachers, research knowledge, science laboratories, and community opinion. In terms of a physics metaphor I like to use, context is the potential of the system for accomplishing learning. A school that contains a well-equipped science laboratory, a highly trained teacher, and motivated students seems likely to have a greater potential for learning than one that has no laboratory, poor teachers, and disinterested students. Whether this potential is realized depends, in part, on the classroom transactions.

<u>Transactions</u> are the set of activities that expose the student to opportunities to learn. They are the actual interactions of the students with their teachers, classmates, curriculum materials, the natural world, and many other things. In terms of the physics metaphor, transactions are the kinetics of the system. Reading the test, talking with other students, watching a film loop, and visiting a zoo are all examples of transactions that would seem to be related (in different ways) to science learning.

Outcomes of the schooling process are the results of transactions occurring in a given context. Outcomes are the work accomplished by the system. An understanding of the theory of evolution is an example of an outcome. So is the skill to read a thermometer or use a pipette. A more negative attitude toward scientific research on the part of the teacher is still another example of an outcome of science education. Outcomes are usually measured by changes in student behavior, but teachers, activities, textbooks, and other actors and props in the drama of learning may be affected as well.

A list of the key elements of these three components is shown in Table 1.

Table 1

Domain of Science Education

| Context (antecedent conditions) | Transaction (interactions) | Outcomes |
|---|---|---|
| Student characteristics | Student Behavior | Student Achievement |
| Teacher characteristics | - Direct | Student Attitudes |
| Science | - Indirect | Student Skills |
| School Climate | Teacher Behaviors | Teacher Change |
| Societal imperatives | - Pedagogy | Scientific Literacy |
| Home environment | - Style | Career Choices |
| Curriculum Materials | - Management | Institutional Effects |
| Facilities/Equipment | Instructional Resource Exposure | |
| Goals | Classroom Climate | |
| Science Education Network | External Intrusions | |

Table 2 provides examples illustrating each of the 22 elements. Although I do not claim that this list is exhaustive, it does provide a structure--perhaps a check list--for considering areas needing research.

## SYNTHESIS OF RECENT RESEARCH

Time and space limitations do not permit a complete review of all science education research. However, several major research syntheses were available, and these were used as the major data sources in my review. The yearly reviews of research supported by ERIC-SMEAC, several meta-analyses, the NSF-supported status studies, National Assessment results, and the work of Project Synthesis provided a rich source of information for making a preliminary assessment of our current knowledge of science education. Each of these reviews was examined for conclusions relating to the context, transactions, and outcomes of science teaching. The results of that examination follow.

Table 2

Domain of Science Education*
Examples of Categories

Context (entry conditions)

- Student Characteristics (interests, previous experiences, abilities, attitudes)
- Teacher Characteristics (philosophy, preparation, perceptions, personal traits)
- Science (content, processes)
- School Climate (bureaucracy, policies, physical appearance, community influences)
- Societal Imperatives (environmental quality, societal views of science and/or technology, health, and well being)
- Home Environments (vocation, family structure and function, physical features, philosophy)
- Curriculum Materials (texts, laboratory guides, films)
- Science Facilities (classroom/laboratory, materials, budget)
- Goals (philosophy of students, school board and other outside groups, departmental)
- Science Education Network (communication groups, professional societies, research reports, cooperative efforts)

Transactions (interactions)

- Teacher Behaviors (procedures followed to promote instruction)
- Student Behaviors (activities of students in the classroom)
- Instructional Resource Exposure (enrolling in science, TV, engaged time)
- Classroom Climate (social-psychological learning environment)
- External Influences (strikes, budget cuts. space launchings)

Outcomes (results of instruction)

- Student Achievement (test scores, other measures)
- Student Attitudes (student feelings about science and science learning)
- Student Skills (observation, measurement)
- Teacher Change (satisfaction, burn-out, knowledge)
- Scientific Literacy (more knowledgeable about the meaning, limitations, and value of science)
- Career Choices (science or science teaching)
- Institutional Effects (loss of status, morale, structure changes)

Source: Modified from Yager, 1978.

## Context

The relationships between student characteristics and student performance were investigated in an exhaustive meta-analysis conducted by Malone and Fleming (1982). Meta-analysis is a quantitative procedure for synthesizing the results from a number of similar studies (Glass and Smith, 1979). Approximately 170 studies were found between 1960 and 1981 that examined the influence of ability, social-economic status (SES), gender, and race on student outcomes. Student outcome measures included science achievement, science attitudes, and cognitive levels (e.g., Bloom or Piagetian tasks). Both correlation coefficients and effect sizes (differences between experimental and control groups expressed in standard deviation units) were used as indicators of relationships. Table 3 presents a portion of the Malone and Fleming findings.

Table 3

Student Characteristics and Outcomes: Mean Correlations

| | Student Achievement | Student Attitude | Cognitive Level |
|---|---|---|---|
| General Ability | .43 (42)* | .15 (13) | .47 (112) |
| Language Ability | .41 ( 5) | NA ( 5) | .53 ( 24) |
| Mathematics Ability | .42 (13) | NA ( 5) | .51 ( 19) |
| SES (high-low) | .25 (21) | .03 (13) | .29 ( 47) |

*Number of studies in parentheses.

Source: Malone and Fleming, 1982.

Measures of ability (e.g., IQ) show consistent and positive relationships with achievement and cognitive level. Their relationships with attitudes are much smaller (r = 0.15), but few studies have been done in this area. SES correlates lower with achievement and cognitive levels and essentially as zero with student attitudes.

Table 4 presents the results of an analysis conducted using effect sizes as the measure of relationship. These are standardized differences between two groups. In each case, a positive effect size favors the first group listed.

Table 6

Student Traits and Outcomes: Mean Effect Size

| | Student Achievement | Student Attitude | Cognitive Level |
|---|---|---|---|
| Gender Male/Female | .16 (45)* | .08 (31) | .13 (96) |
| Race Anglo/Black | .41 (15) | .10 (11) | .42 (34) |
| Race Anglo/Hispanic | .26 (13) | .05 (11) | .32 (32) |

*Number of studies in parentheses.

Source: Malone and Fleming, 1982.

Gender appears to have the weakest relationships with the three performance measures considered, with males generally scoring higher than females. The effect size for race is about twice as large as that for gender--except for attitudes, where the relationships are quite low.

Clearly, there are consistent relationships between student characteristics and student outcomes. Further, a great deal of work has been done, to date, in this area. However, the low relationships between student characteristics and attitudes and the few studies done in this area are possible areas for future research.

Teacher Characteristics

As part of the extensive meta-analysis carried out at the University of Colorado (Anderson, 1982), Sweitzer (1982) examined the effectiveness of preservice and inservice training activities, such as method courses, modeling strategy, and questioning analysis, for teachers. When using various teacher outcome criteria as the dependent measures, Sweitzer noted a mean effect size of 0.77 in 153 different studies. That is, teachers who receive the training tended to outperform the comparison groups on measures of science content, process, attitude toward science, and desired teaching behaviors (e.g., questioning). This would lead one to believe that training does have at least a short-term effect on teacher performance.

A few studies (n = 19) used subsequent student performance as the criteria for assessing teacher training impact, but Sweitzer (1982) provided no data on long-term behavior changes for the trained teachers. A mean effect size of 0.44 was observed for these studies, which suggests that training teachers may have an eventual impact on students.

By contrast, Druva's (1982) meta-analysis yielded very little relationship between teacher characteristics and their teaching behavior. The mean correlation between various characteristics (e.g., age, gender, personality, attitudes, and measures of effective teaching) was only + 0.05, perhaps the most surprising result in this series of meta-analyses. Druva (1982) also found low correlations among her measures of teacher characteristics and student outcomes. Several of these results are shown in table 5.

Table 5

Teacher Characteristics and Student Outcomes: Mean Correlations

| Characteristics | Student Outcomes Cognitive | Affective |
|---|---|---|
| Sex | .04 ( 4)* | .08 ( 7) |
| Age | .13 ( 7) | .26 ( 1) |
| Science Training | .19 ( 24) | .18 ( 9) |
| Experience | .10 ( 23) | .12 (11) |
| Personality | .01 (144) | - .02 (53) |
| Attitudes | .10 ( 6) | .04 (11) |
| | .05 (208) | .04 (92) |

*Number of studies in parentheses.

Source: Druva, 1982.

Note that previous science training accounts for very little of the variation in student performance. This is contrary to the beliefs held by many scientists and science educators that science knowledge is highly related to effective teaching. Only 4 percent of the variation in student learning can be explained by this variable. Furthermore, the unknown influence of age, experience, and sex on this variable may further decrease this relationship.

For reasons that are not too clear, antecedent teacher characteristics do not appear to have much effect on student performance in science. This result will surprise and disappoint many people, but it is a finding that cannot be ignored.

Science

This category refers to the content, process, and structure of the scientific enterprise. Research in this category asks questions about the nature of science as it relates to student learning. For example, are there characteristics of physics as an area of study that suggests learning styles or methods of presentation different from those deemed effective in biology or earth science? The Anderson (1982) meta-analysis did not address this issue, and few studies were found in the other research reviews examined for this paper.

Occasionally, teachers or students would be asked their views of science; for example, is it factual or abstract, inductive or deductive (Durkee, 1975)? Cognitive psychologists have examined the way in which people learn concepts, including the concepts of science. However, their approach derives from information theory, not the nature of science. Several tests have been developed to measure understanding of attitudes toward science (Doran et al., 1974), but I found no research on the nature of science with potential implications for science teaching.

Social Imperatives

The influence that society has on teaching and the effect that societal expectations have on curriculum development have not been well researched in science. Yet these are timely and important issues. Nationally, there are frequent reports of various citizen groups influencing the inclusion or exclusion of controversial materials in the curriculum. Public concern about the decline in science literacy—as evidenced by scores on national assessments—has prompted increased citizen involvement in educational decision-making for many districts.

In addition to the concern of citizens, scientists and science educators fear that basic levels of science literacy are not being met. Science literacy is crucial for an informed electorate in the increasingly technological society in which we live. With evidence of reduced enrollments in science classes, there is a concern that future citizens will be even less capable of grasping the essential scientific ramifications of many societal issues. This concern has prompted the inclusion of technology and science-society items on the National Assessment of Eduational Progress test in science. In addition, the NSTA recently issued a policy statement on the importance of including the social aspects of science in the science curriculum (NSTA, 1982).

Home Environment

Home environment has been shown to be significantly related to student performance in a few national and international studies, but it is not an area where many researchers have turned their attention. In the United States, Wolf (1979) reported a correlation of 0.43 between measures of home and family conditions and science achievement as measured in the first International Evaluation of Achievement (IEA) study. Coleman (1966) reported even larger relationships between home environment variables and measures of verbal ability.

Wolf's study is informative because it compares the relative contribution of home previous learning, and school variables on student performance. His results for three different age groups are shown in Table 6.

Table 6

Multiple Regression Results for
Predictors of Science Achievement

| | Home Learning | | Prior Learning | | School Variables | |
|---|---|---|---|---|---|---|
| Age Level | R | Variance Explained | R | Added Variance | R | Variance Added |
| 10-yr.-olds | .42 | 18 | .43 | 0 | .52 | 9 |
| 14-yr.-olds | .45 | 21 | .49 | 3 | .55 | 6 |
| 12th graders | .43 | 18 | .52 | 9 | .59 | 8 |

Source: Wolf, 1979.

These results illustrate the influence of the home environment and previous learning science performance. They also suggest that school variables do make a difference even when entered last in the regression analysis. Butts (1981) reached a similar conclusion in his review of the science educational research conducted during 1979. Others have noted the importance of home background in their secondary analysis of NAEP data (Walberg et al., 1981).

## Curriculum Materials

The curriculum to which students are exposed does make a difference in what students learn. The research literature is replete with curriculum studies, and most find that students learn the content to which they are exposed. In 1979 alone, Butts (1981) found 102 curriculum studies. He concluded that content effects were largely unexplored at the elementary level, but at the secondary level, instruction in specific content increases achievement in that area.

Shymansky et al. (1982) did a meta-analysis of 130 studies that investigated the effectiveness of secondary-level NSF curricula in comparison to traditional science programs. Their outcome measures consisted of cognitive tests, affective scales, process and analytical skills, and creativity. They found a mean effect size of 0.37 in favor of the NSF curricula. However, specific areas stressed in these innovative curricula showed even greater differences. The mean effect size for process skills was 0.61, for analytical skills, 0.71, and for creativity, 0.71.

Weinstein et al. (1982) analyzed 33 studies from the United States, Great Britain, and Israel and found in them 151 separate comparisons. The mean effect size was 0.31, with a standard deviation of 0.70. This is in close agreement with the Shymansky et al. and the Wise and Okey (1982) results.

In terms of subject areas, biology and physics showed the greatest effects. In biology, the mean effect size for achievement was 0.59, for perception, 0.82, and for process skills, 0.90. For physics, the achievement effect size was 0.50, perception, 0.33, and process skills, 0.53. Earth science was the only subject area with a negative effect size (-0.07).

Welch (1979) acknowledged that curriculum differences do have an effect, but argued that the magnitude was small, perhaps explaining only 5 percent of the variance. Shymansky's data suggest that the average student in the experimental curriculum would fall at the 64th percentile of the comparison group, a difference of 14 percent.

Several authors raised questions about the extent of curriculum exposure, failure of the curriculum to represent modern science, and the relative influence of curriculum compared to other context and transactional variables. In spite of these concerns, curriculum effects represents one of our most researched areas and one in which our conclusions seem fairly solid.

Facilities/Equipment

This category is related to the school climate and curriculum materials category, but focuses on the tools available for teaching and learning. Climate is the socio-psychological context of the school; curriculum refers to the definition of content to be learned. Facilities and equipment refers to such things as laboratory equipment, desks, classroom architecture, computers, chalk boards, projectors, and the like.

Helgeson et al. (1977), in their 20-year study of the status of science education, concluded that teachers believe that adequate facilities are one of the most important conditions for a good science program. Flexibility of usage is also rated as very important. These conclusions were based on surveys conducted by a number of researchers. The general tone of the review was concern for the perceived decline in science budgets. In the national survey of science practices (Weiss, 1978), 25 percent of the teachers polled rated the lack of funds for purchasing equipment and supplies as a serious problem.

Most research conducted in this area has been directed toward the use of the equipment in learning science, rather than toward the intrinsic merit of the materials. For example, filmed instruction or computer-assisted instruction (CAI) is compared to traditional modes of instruction using student performance as the criterion. Renner et al. (1978) reported on nine such studies in their review; Mallinson (1977) found eight studies in 1975. In each case, the emphasis was on the use of the tool rather than on the need, development, or structure of facilities and equipment. Perhaps research is needed to help science teachers decide what equipment is needed to teach science, how it should be built, and how it should be presented to students. Some potential areas of study include hand-held calculators, microcomputers, films, film loops, electrical equipment, telescopes, and the like. Do we need them? Why or why not? What are their intended uses?

## Goals

Research on the goals and objectives of science education sometimes takes the form of surveys of teachers or science education professors. They are given a list of potential goals and asked to rank them. For example, Welch (1977) surveyed 344 science teachers and 167 principals and asked them to identify needed goals. Three major needs surfaced: (1) information processing and decisionmaking skills, (2) basic skills, and (3) development of self-esteem.

More often, leading figures or organizations are asked to identify priorities for the discipline. For example, Hurd (1971) identified what he saw as emerging priorities. Some of those stated were: (1) science must be part of the education of every student, (2) science should be taught in a social context, and (3) science education should give top priority to changes brought about by technological developments.

Perhaps the most extensive research effort to date in goals was the work of the Project Synthesis group (Harms and Yager, 1981). A group of 23 leading science educators established desired conditions for science teaching using a framework of four goal clusters: personal needs, societal issues, academic preparation, and career education awareness. These desired conditions were then used to examine the current status of science teaching to determine needs. Discrepancies in biological science, physical science, inquiry, elementary science, and science-technology-society were identified and used to develop a series of recommendations for Federal policy as well as for science teachers. During the past year, the goals (as portrayed by Project Synthesis) have been used as criteria for identifying the outstanding science programs in the United States. A list of the goals has also been distributed widely to science teachers through the National Science Teachers Association.

Historical and philosophical research on goals appears to be unpopular (perhaps unproductive) to researchers, as few studies of this kind were found in the major data sources used in preparing this paper.

## Science Curriculum Networks

No research was found that addressed the effectiveness of professional societies, cooperative efforts, dissemination systems, or scholarly journals in the area of science education. Annual meetings, ERIC-SMEAC, The Science Teacher, and meetings like the NIE conference on the mathematics/science teacher shortage are seldom researched for improvement or accountability. Some work has been done by Crane (1972) on the influence of the "invisible college" on professional behavior, but not specifically in science education.

## Transactions

Transactions are the kinetics of the learning system. They are the activities that students, teachers, and others perform in the quest for knowledge. Five major categories of transactions have been identified and are examined in turn.

## Student Behavior

It is difficult to separate student behaviors from teacher behaviors because they often occur simultaneously. That is, a teacher lectures and a student listens to a lecture. The distinction I would like to make is that of the initiator. Who decides what activity is to occur? The teacher decides to lecture, but the student decides to listen.

Surprisingly little research on student-initiated behaviors was found in the literature I reviewed. In fact, only one of the four yearly reviews with indexes even had the word "student" listed, and that was for a section on student characteristics. Data from the set of case studies carried out by Stake and Easley (1978) are even more surprising. Their extensive index has 290 references to "teacher" (plus another 96 on "teaching"), but only eight references to student! Apparently this has not been a popular focus for science education researchers.

Some work has been done on how students choose to allocate their time and effort in individualized programs (Bowsyer et al., 1978; Rice & Linn, 1978), but it is premature to form any general conclusions.

One promising line of research is that dealing with the engaged time a student spends on learning. To a large extent, the student is responsible for this kind of behavior. The research to date is encouraging. The more time a student spends in direct learning behaviors, the greater the learning (Doyle, 1977). Direct learning behaviors include such things as task completion, time on task, homework, and reading texts. In a sense, one key student behavior is his or her decision to enroll in a science course, which is discussed further in the section titled "Instructional Resource Exposure." Much more remains to be learned, but the application of these principles to science learning seems warranted.

Another set of interesting student behaviors are those that mediate learning (Doyle, 1977). Mediating behaviors are those mental processes that we presume are necessary for effective learning, but that are not directly related to the learning process. Examples include attending, translating, segmenting, rehearsing, and elaborating. Although not related specifically to science learning, the influence of these behaviors in the science classroom seems worthy of further investigation, especially during laboratory investigations.

An interesting new line of research on behavior falls into another category of indirect behaviors and grows out of conceptualizing the classroom as an ecological system. Learning is viewed in the context of "exchanging performance for grades." The student does things in return for certain rewards--grades perhaps, or in some cases the satisfaction of understanding.

The approach seems somewhat crass but presents an innovative way to view science classrooms. The research to date suggests that successful students search for cues from the teacher on important concepts, imitate desired behavior, and even enlist cohort assistance. Other student behaviors important in this approach to the classroom are adjusting to change and learning to compensate for deficiencies, absenteeism, reading problems, etc. Some intriguing applications for the science education researcher seem possible.

A final form of relevant student behaviors are those occuring in informal or out-of-school settings. A few research studies have been conducted on the effectiveness of museums, zoos, field trips, television, and the like. However, it is premature to form generalizations at this time. The growing acceptability of naturalistic inquiry paradigms might permit a greater understanding of what students do when they attempt to learn science in informal settings.

Teacher Behaviors

The literature is crowded with studies of teacher behavior. It is a primary area for research in science teaching and has been addressed in two major meta-analyses (Wise and Okey, 1982; Willett and Yamashita, 1982).

I classify teacher behaviors in terms of pedagogy, style, and management. Pedagogy refers to the specific instructional strategies and tactics teachers use in the classroom. It includes such things as lecturing, lab work, and questioning behavior. Style is the manifestation of the teacher's personality in the classroom, and it includes things such as enthusiasm, sensitivity, and expectations. Management is a broad category including general instructional systems—CAI, team teaching, and such day-to-day tasks for structuring the learning opportunities as setting rules and modeling behavior.

Wise and Okey (1982) provide a nice summary of the effects of teacher techniques. Their results are shown in Table 7. The overall effect size of the various teaching techniques was 0.34, one-third of a standard deviation. This means that the average of the treatment group was equivalent to the 63rd percentile of the comparison group. The impact seems modest except for wait-time, and this research involved only four studies. Wise and Okey recognize these moderate effects on student learning but offer the hope that combining strategies might improve the situation. They call for additional research to investigate the possibilities.

Willett and Yamashita (1982) conducted a meta-analysis of research on instruction systems, which they defined as "a general plan for conducting a course over an extended period of time." (p. 1) Examples include CAI, individualized instruction, and mastery learning. They examined research carried out between 1950 and 1980 and found 130 studies that fit their criteria for inclusion. Most were conducted between 1961 and 1974. The results of their analysis are informative and are presented in Table 8.

The overall impact of the various instructional systems was only 0.10, indicating that, on average, an innovative teaching system will be about only one-tenth of a standard deviation better than "traditional" science teaching. There were no effects noted for grade, subject matter, or year of publication. Published results tend to yield higher effect sizes than those appearing in dissertations.

Table 7

Teacher Behaviors: Mean Effect Sizes

| Technique | Mean Effect Size | Standard Deviation | Number of Cases |
|---|---|---|---|
| Wait-time | .90 | .43 | 4 |
| Focusing (e.g., organizers) | .57 | .91 | 28 |
| Manipulative (by students) | .57 | .64 | 24 |
| Modified (specific content) | .52 | .45 | 22 |
| Questioning | .48 | .39 | 13 |
| Inquiry-discovery | .32 | .73 | 58 |
| Testing (e.g., diagnostic) | .32 | .46 | 45 |
| Presentation Mode (e.g., team teaching) | .26 | .56 | 103 |
| Teacher Direction (extent of) | .23 | .66 | 45 |
| Audiovisual methods | .18 | .48 | 33 |
| Grading (e.g., pass-fail) | -.15 | .38 | 14 |
| Miscellaneous | .43 | .26 | 12 |
| Total | .34 | NA | 411 |

Source: Wise and Okey, 1982.

Table 8

Instructional System: Mean Effect Size

| System | Effect Size | Maximum | Minimum | No. of Cases |
|---|---|---|---|---|
| Audio-tutorial | .17 | .52 | -.27 | 7 |
| Computer Linked | .13 | 1.45 | -.58 | 14 |
| Learning Contracts | .47 | 1.74 | -.38 | 12 |
| Dept. Elementary School | -.09 | .08 | -.25 | 3 |
| Individualized Instruction | .17 | 1.74 | -.85 | 131 |
| Mastery Learning | .64 | 1.74 | .08 | 13 |
| Media-based | -.02 | 1.22 | -.87 | 100 |
| PSI (Personalized System of Instruction) | .60 | 1.74 | .08 | 15 |
| Programmed | .17 | 1.36 | -.82 | 52 |
| Self-directed | .08 | .87 | -.58 | 27 |
| Source Papers | .14 | .48 | -.19 | 13 |
| Student Assisted | .09 | .34 | -.13 | 6 |
| Team Teaching | .06 | 1.36 | -.76 | 41 |
| Total | .10 | 1.74 | -.87 | 341 |

Source: Willett and Yamashita, 1982.

Lott (1982) conducted a meta-analysis of studies involving the use of advance organizers and inductive versus deductive teaching behaviors. He found a mean effect size of 0.24 for 22 studies using advance organizers and 0.06 for the studies that examined inductive versus deductive teaching behaviors. His results are lower than those found by Wise and Okey (1982), but the latter included a broader definition of the categories.

In summary, the effects due to various teaching strategies are disappointingly low. They average only 0.22 for the 812 cases used in these three meta-analyses. Here, again, the influence of what the teacher does in the classroom appears minimal. Perhaps a different research focus is needed.

Little work has been done in science on teacher style variables and the teacher as manager. Rosenshine and Furst (1971) argue that behaviors such as organization, enthusiasm, and expectation are key factors in facilitating learning. They believe that direct teaching strategies have greater impact than indirect ones. Some data reported here tend to support this claim in science teaching (see, for example, effects of focusing, learning contracts, and mastery learning). Indirect strategies (e.g., inquiry teaching, self-directed systems, and inductive teaching) seem less successful. The discovery nature of science, however, makes these results unpalatable for many science educators. Interest in induction, inquiry, and discovery learning do not match well with the direct teaching proponents.

Instructional Resource Exposure

This category includes those activities carried out by teachers, students, and others that bring learners in contact with learning opportunities. To some extent, they overlap with the teacher and student behaviors mentioned earlier. However, the emphasis here is on the interaction of the students with the learning opportunity. Key elements include enrolling in science classes, curriculum implementation, minutes of science studied, library use, watching TV, taking field trips and reading science novels.

Research in this area is limited in the context of science learning. Course enrollment data are uneven in quality, although a few studies of the past decade are beginning to shed some light. Engaged time in science is perceived as decreasing, yet our logic and some research (Welch et al., 1981) tells us that taking courses is an essential ingredient for learning science.

The barriers to and facilitators of getting children into science courses are not well understood. Furthermore, we are not certain of the most effective activities to offer once we get them there.

The results of the 1982 National Assessment indicate marked changes on topics covered by the national media (Welch et al., 1983). Items on test-tube babies, computers, space travel, nuclear energy, pollution, and others all showed sharp changes during the past 5 years. Why? What are the implications of these results for the learning of science? These and other questions remain unanswered.

Although some evaluation of out-of-school activities has occurred, it is too early to form generalizations. One cautionary note to the hopeful: out-of-school activities are usually nondirective. They present a resource (e.g., zoo exhibits) and ask--by implication only--"what can you learn about animal behavior?" Indirect strategies have not been overwhelmingly successful. Further information and understanding is needed.

Classroom Climate

Classroom climate is the social-psychological environment in the classroom as perceived by the students. This category views the class as a social group and presumes that group dynamics is an important factor for learning. Emphasis is on the social and psychological interactions in the classroom and their effect on learning.

One measure of the learning environment is the Learning Environment Inventory (LEI) developed in the late 1960's (Fraser et al., 1982). Considerable research in North America, Australia, Israel, India, and other countries has shown relationships between the LEI scales and student performance. In many studies, appreciable amounts of variance are explained beyond student entry characteristics such as IQ and pretest scores. Much of the research has been done in science classes.

The work of Johnson et al. (1981) has also shown relationships between group activity and student learning. Cooperative learning structures were found more effective than competitive or individualized learning structures in nearly all cases reviewed. The mean effect size of 0.78 indicates the importance of the social environment for learning.

External Intrusions

Often, the classroom is affected by events in the community, the Nation, or the world. Examples of such events include budget cuts, space launches, censorship, evolution court trials, course requirements, teacher firings, and strikes. These activities probably influence the attitudes, the career choices, and even the achievement of students.

Helgeson et al. (1977) examined these issues in their review of the status of science education. They concluded that such factors do have influence in the science literacy of a nation but did not describe how they operated.

Stake and Easley (1978) reported an increased intrusion of Federal and State offices into the conduct of education. As a result, administrators are forced to spend more time as business managers and less as educational leaders. Meanwhile, the gap between teachers and administrators widens as each group seeks relief from its respective pressures.

Except for recognizing the influence of external intrusions, researchers have not spent much time in this area. The value of future research is not clear to me, but there may be some potential for investigation.

## Outcomes

### Student Achievement

Performance, or change in performance, on measures of cognitive ability defines student achievement. A great deal of research has been done following the intellectual development model of Piaget, and recent reviews of science education research usually have a section devoted exclusively to Piagetian studies. In 1977, Mallinson reported on 23 such studies. He concluded that (1) the stages postulated by Piaget seem to be supported by other researchers; (2) the logical operations of classification, seriation, and so on are not as hierarchically ordered as many have been led to believe; and (3) adolescents may not fit the classification of "formal operational" to the extent that Piaget suggested.

Many researchers have tried to measure students' ability to perform various Piagetian tasks and then relate these scores to course achievement or other measures of student ability. The relationships are strong. This research, which is reviewed in Table 3, shows a mean correlation of 0.47 between general ability and cognitive level.

My familiarity with this research is limited, but I believe that researchers have identified a new set of student variables to measure (e.g., conservation) and then searched for correlates of the scores (e.g., age, sex, science success, IQ). By better understanding the nature of student learning, they hope to do a better job of teaching. This approach seems reasonable, but success to date has been limited. Different children learn different concepts at different times. Stage of development is content specific, forcing researchers to examine the learning of very small bits of information. Generalizability to a whole course seems far off, if attainable at all.

Another set of researchers have focused on the nature of learning in a field sometimes called "cognitive science." Some have applied the theories of cognitive science to science education (Klofer and Champagne, 1982). Some of the key tenets of recent cognitive development work include recognition that new learning relies on previous learning, that information is retained through relationships (schema), and that learners construct understanding rather than mirror what they are told (Resnick, 1982). Here again, the cognitive researchers believe that understanding how children learn will lead to improved instruction.

Other observers of the science education scene are less convinced. Stake and Easley (1978) wrote: "Research on the context of instruction rather than research on the learner is more likely to yield insights into ways of improving the quality of education that is offered. What research on the learner tells us is the vast number of ways people differ, and how greater experience increases those differences" (pp. 19-26). They believe that research on the manipulative variables such as administrative or social-political background offer more hope for school control.

Other research on student outcomes has concentrated on improving the techniques for measuring student learning. Tests that measured such things as the nature of science, cognitive preferences, higher levels of Benjamin Bloom's cognitive taxonomy, inquiry skills, logical thinking, and a variety science content (e.g., marine biology, ecology, physics) have been developed and analyzed. Much work exists in this area, but it is difficult to summarize its progress. Many tests have been developed and used to evaluate programs and predict future success in science, and these tests have been the focus of many dissertations. Some reviewers have pointed out the limitations of many of the measurement techniques (Butts, 1981; Mallinson, 1977); others have applauded the improvement of our testing procedures (Sipe and Farmer, 1982). Many student outcomes have been measured and researched. The influence of Bloom's taxonomy has been great, and tests are now superior to those of 25 years ago. Further improvement will probably grow out of entirely new approaches and procedures for measuring outcomes.

A great deal of time and effort has gone into the periodic national assessment in science conducted by the National Assessment of Educational Progress (NAEP). We have monitored the state of the Nation's understanding on four occasions, 1968-69, 1971-72, 1976-77, and 1981-82. Data gathered from this process have been useful to policymakers and researchers and merits continuation.

A similar effort occurred in 1973 with the International Evaluation of Achievement (IEA) study in which science performance was assessed in 19 countries. Another international assessment will take place in 1983 in nearly 40 countries.

Research on the influence of contextual and transaction variables was reviewed earlier. Measures of student outcomes were used as criteria of effectiveness. Much of the research on student outcomes occurs this way. Emphasis is on the influence of the independent variables rather than on the nature of the outcomes measured.

The most extensive work on outcomes in science emerged from Project Synthesis (Harms and Yager, 1981). Desired student outcomes were proposed for five groups — biology, physical science, inquiry, elementary science, and science-society-technology interactions. Evidence on the actual status of student outcomes was examined in light of the desired state, with discrepancies used to identify future needs for science teaching. The work which represents a milestone for research on outcomes of science teaching, has been used to help identify exemplary science programs in this country.

## Student Attitudes

Work in the development and measurement of student attitudes is not as advanced as that in the cognitive domain, although there is a great deal of current activity. In fact, Ormerod and Duckworth (1975) covered about 500 attitude studies in their review. A number of attitude scales have been developed and used in various studies, but some reviewers have seriously questioned their quality (Gardner, 1975). Although some developmental psychologists have explored the affective domain (Rest, 1979), not many have examined attitudes in a science context. Theoretical development is limited.

Attitudes have been used as criteria for research on context and transaction components, and they were included in the last two National Assessments. The first IEA assessment included attitude scales, but many did not meet acceptable levels of reliability and were dropped. Only four were eventually analyzed. The 1983-84 IEA study will also try to measure attitude outcomes, but the nature of the scales has not yet been determined.

The Project Synthesis team specified a number of desired attitude outcomes, and each of the five focus groups (biology, inquiry, etc.) recognized the importance of affective outcomes. Each of the research reviews contained sections on the development and need for good attitude measuring procedures. Most, however, called for continued development in the area. A need was seen for clearer understanding of the role attitudes play in understanding science, influencing future behavior, and affecting future career choices in science and technology.

Benjamin Bloom published his cognitive taxonomy in the mid-1950's. James Krathwohl followed with a taxonomy for the affective domain 8 years later. In my opinion, this 8-year lag partially explains the current lag in our ability to effectively measure attitude outcomes.

Student Skills

Skills in science denote the techniques students learn in science classrooms (e.g., reading meters, taking measurements, conducting experiments), as well as those behaviors exhibited by students after they leave school (e.g., brushing teeth, voting, building nature reserves).

Some work has been done on methods for measuring process skills, especially at the lower grades. Observation, classification, and categorization tests have been developed and used, but they have yielded inconclusive results (Mallinson, 1977). With directed efforts, students have shown gains on process skill measures, but there is a concomitant loss in content knowledge. In other cases, no significant gains were detected.

Some have attempted to measure laboratory performance skills and have developed new techniques (Butts, 1981). However, most national testing programs do not include "practical" tests, and there is mixed opinion on the value of such approaches given their high cost. The limited number of studies preclude generalizations.

The third part of the Bloom-Krathwohl effort was the psychomotor domain, for which they intended to develop hierarchical taxonomy of objectives. Their failure to accomplish this task characterizes the situation in science teaching! The outcomes are considered important, but the barriers to effective development are formidable. Some people are attempting to move us forward in isolated studies, but no strong interest is evident at present.

Teacher Change

Teachers are often involved in the transactions that occur during the learning of science. It seems reasonable to expect that teachers change as a result of those experiences. They may learn more science, develop negative attitudes, or even become so frustrated they leave teaching. We know from the Sweitzer (1982) study that teachers change as a result or training, but we know very little about how (indeed, whether) teachers change as a result of teaching. Teacher burn-out and aging are examples of how teachers change, but I found no studies of science teachers that addressed these issues. This appears to be an area where little research has occurred.

Some teachers have left science teaching, thereby contributing to the shortage. But the reasons appear to reflect economic conditions more than the impact of science teaching. A few surveys proclaimed that there is a severe shortage of science and mathematics teachers in the United States (Guthrie and Zusman, 1982) and suggest budget cuts, problem students, and, most important, higher salaries in the private sector as reasons for the shortage. But these are speculations, not research findings.

Most likely, studies on teacher supply and demand, selection, and retention will be done by general teacher educators or administrators, rather than by science educators. However, the current shortage of qualified (whatever that means) science teachers may attract attention from the science teaching community. This issue is discussed further in the section on "Career Choices" below.

Scientific Literacy

A scientifically literate populace is an oft-stated goal for science teaching. Literacy generally means that set of cognitive, affective, and behavioral outcomes needed for a citizen to live in our technologically oriented world. Research in this area has taken two paths. Some have tried to define, through research, the essential components of science literacy. Others (NAEP) have measured the components of literacy, which were discussed in the preceding three sections.

Several researchers have assessed the requirements for science literacy as implied by the mass media (Ayers, 1980), while others have attempted to measure the literacy of science teachers (Ogunniyi and Pella, 1980) or adults (Miller, 1981). In many instances, literacy is used synonymously with knowledge about the nature of science. Others define it as the knowledge and attitude toward the process and products of science. Because literacy has multiple meanings and is a common goal of science teaching, it certainly qualifies for further study. The payoff of such work is not clear, however, because of our limited prior experience in the area.

Career Choices

One outcome of science teaching is a student's decision to pursue a career in science or science teaching. Factors influencing career choices have been studied, and the causes for underrepresentation of women and minorities in science careers have been examined with considerable interest.

Sipe and Farmer (1982) report that 12 percent of all studies reported in 1977-80 dealt with the career development of scientists and science teachers. An intriguing study by Lagemann (1980) uses an approach capable of broader implementation. Lagemann followed 90 teachers trained in science and found that those who left teaching were mostly female and had weaker science backgrounds than those who stayed in teaching. The reasons cited for leaving teaching were large classes, nonteaching school duties, and lack of student interest. Those who prepared for teaching but were not hired were younger, had lower SAT scores in mathematics and science, had higher GPA's, and declared an interest in teaching later in undergraduate programs.

Welch and Lawrenz (1982) found significant differences in the characteristics of male and female teachers. Apparently, the career decisions for men and women were based on different factors.

Unfortunately, no synthesizing studies of career choices were found, but I believe that additional studies of teacher and scientist selection, retention, and attrition would be beneficial. The implications for preservice and inservice training, for recruitment, and for resolving shortages (or surpluses) appear great.

## Institutional Effects

Are schools and other institutions changed as a result of science instruction? If so, in what ways? As science programs are cut back or dropped from the curriculum, what is the effect on the school? How has the NSF changed since the science education budget was cut from $100 million to $15 million? If departments of science teaching were (and are) cut from colleges and universities, what changes in the institution can be seen? Conversely, if programs are added to our schools, colleges, and informal science centers (e.g., zoos, museums), how are these institutions going to change?

I found very little that addressed these questions. The Stake and Easley (1978) case studies examined the influence of the community on the schools, but not the influence of the schools on the community. This was true also of the Helgeson report (1977). Mallinson's review (1977) included a number of areas where impact might be expected, notably bilingual instruction, mainstreaming, and desegregation. But apparently no research dealt with changes in the school resulting from special science programs for the bilingual, the handicapped, or minorities. Perhaps it is unrealistic to expect much institutional change as an outcome of science instruction.

## SOME CONCLUSIONS

This comprehensive analysis enables me to sketch a picture of our current knowledge of science teaching. To be sure, the sketch will be hazy. Nonetheless, a broad view of the discipline helps identify gaps in our knowledge, promising lines for future research, and areas of success.

My synthesis of recent research is summarized in Table 9. The quantity of research for each element of the domain is estimated in the second column. A 5-point rating of very much, much, some, little, very little was used. Our current knowledge of each element is estimated in the third column, again using a 5-point scale from very slight to very strong. In some cases (e.g., teacher characteristics), two aspects of the element are reported because of different conclusions. When available, meta-analysis results are reported in the table as mean correlations or effect sizes.

TABLE 9

Summary of Research Synthesis

| Element | Research Amount | Extent of Known Impact/Influence | Estimated Future Potential |
|---|---|---|---|
| **Context** | | | |
| Student Characteristics | Very much | Moderate-achievement(40%)* Slight-attitudes (.10)* | Low-achievement High-attitude |
| Teacher Characteristics | Very much | Strong-training(.77)** Very slight-student outcomes(.05)* | Low |
| Science | Very little | Slight | Unknown |
| School Climate | Some | Moderate | High |
| Social Imperatives | Very little | Very slight | Unknown |
| Home Environment | Little | Moderate (.43)* | High |
| Curriculum Materials | Very much | Moderate (.37)** | Medium |
| Facilities/Equipment | Some | Slight | Unknown |
| Goals | Little | Very slight | Little |
| Science Education Networks | None | None | Unknown |
| **Transactions** | | | |
| Student Behaviors | Very little | Strong | High |
| Teacher Behaviors | Very much | Slight (.22)* | Little |
| Instructional Resource Exposure | Little | Strong in mathematics (.70)* | High |
| Classroom Climate | Some | Strong (.78)** | High |
| External Intrusions | Very little | Unknown | Unknown |
| **Outcomes** | | | |
| Student Achievement | Very much | Strong | Medium |
| Student Attitudes | Much | Slight | Medium-high |
| Student Skills | Little | Slight | Low |
| Teacher Change | Little | Slight | Medium |
| Scientific Literacy | Little | Slight | Unknown |
| Career Choices | Some | Moderate | Medium-high |
| Institutional Effect | Very little | None | Unknown |

* Mean correlation
** Mean effect size

The fourth column represents my estimate of the impact potential for future research in each area. High ratings appear for categories indicating gaps in our knowledge (student behaviors); high potential areas where preliminary work has been encouraging (classroom climate); or high priority, due to pressure to solve a problem (career choices). Low rated elements are those already heavily researched with either discouraging results (teacher behaviors) or ambiguous or uncertain effects (student characteristics). Other elements have not been researched enough to estimate their impact potential (changes in institutions).

The key determinants of the most promising elements are a moderate amount of work to date and evidence of impact thus far. Seven elements were identified as the most promising areas for needed research. They were: school climate, home environment, student behaviors, resource exposure, career choices, student attitudes, and classroom climate.

Two context variables, three transactional elements, and two outcome elements make up my preliminary list. The main emphasis is on home, school, and classroom environmental factors, student contact with learning opportunities, and career decisionmaking. Noticeably absent from the list is further study of teachers and teaching behaviors, something that surprised even me. Except for the influence of teacher training programs on teachers, the extensive research on teachers has not yielded promising results. The mean correlation of teacher characteristics with teacher behavior was only 0.05. Behaviors had a mean effect size of only 0.22 when student outcomes were the effect criteria. What students do and the context in which they do it appear more promising than additional investigations of what teachers do.

Other Needs Assessments

The last step in this needs assessment process is to compare the preceding conclusions with those derived from other assessments of research priorities. Five such studies have been conducted in recent years. A brief description of each follows.

In 1976, a committee of seven science educators met to discuss needed research in science education under the co-sponsorship of the National Association for Research in Science Teaching (NARST) and the National Institute of Education (NIE). The group was appointed by the NARST president and chaired by Fletcher Watson of Harvard University. Eight recommendations were proposed based upon the collective judgment of the committee (Yager, 1978). The research priority areas encompassed by these recommendations are shown in Table 10.

The committee report was "accepted" by the NARST Executive Committee, but it never gave its formal endorsement. The fate of the report at NIE is unknown to me. Because of continuing interest by the NARST Executive Committee in the research priority issue, a group at the University of Georgia was empowered to carry out a Delphi study of research needs among NARST members. Thirty-five statements (later reduced to 31) were ranked by 27 percent of the 780 NARST members. The top 14 priority research areas are shown in Table 10 (Butts et al., 1978).

Table 10

Summary of Research Priorities

| Element | Welch | NIE-NARST | Butts et al. | Yeany | Yager et al. | Abraha |
|---|---|---|---|---|---|---|
| **Context** | | | | | | |
| Student Characteristics | | X | X | | | X |
| Teacher Characteristics | | X | X | X | | X |
| Science | | | X | | | |
| School Climate | X | | | | | |
| Social Imperatives | | X | | | | |
| Home Environment | X | | | | | |
| Curriculum Material | | | X | X | X | X |
| Facilities/Equipment | | | | X | | X |
| Goals | | | X | | | X |
| Science Education Networks | | | | | X | |
| **Transactions** | | | | | | |
| Student Behaviors | X | | | | | |
| Teacher Behaviors | | X | X | X | X | X |
| Instructional Resource Exposure | X | X | | X | | X |
| Classroom Climate | X | X | | | | |
| External Intrusions | | | | | | |
| **Outcomes** | | | | | | |
| Student Achievement | | | X | X | X | X |
| Student Attitudes | X | X | X | X | | X |
| Student Skills | | | | | | |
| Teacher Change | | | | | | |
| Scientific Literacy | | X | | | X | |
| Career Choices | X | | | X | | |
| Institutional Change | | | | | | |

In 1978, a group headed by Russell Yeany and supported by the NARST Research Committee distributed a set of research topics to a sample of secondary school personnel. The group comprised about 50 percent teachers, but the total sample size was not reported (NARST Newsletter, 1979). A total of 12 research priorities were ranked by this group, and these are also presented in Table 10.

In 1978, representatives from the science education programs at 28 colleges and universities were asked what they perceived to be the major problems in science education. They were also asked to identify solutions to these problems (Yager et al., 1982). Five of the solutions addressed needed research topics, while another three focused on ways to carry out research more effectively. The five topical areas are indicated in Table 10.

The final survey reported in the literature was conducted in 1979 by Abraham et al. (1982). All members of NARST were surveyed and asked to list five most-needed areas of research and rank them in priority order. One hundred and one persons (13 percent) from the membership responded. Overall rankings were calculated using frequency of nomination and ranking. The top 11 rankings are listed in Table 10. Priority rank number 6 was on the use of research, rather than a research focus, and is not included in the table.

Each of the preceding assessments was examined in light of the domain described in this report. Because different classification schemes were used in the various studies, some judgment was necessary in transferring priority elements to a common domain. For example, three different priorities in the Butts et al. survey were listed under the category "teaching behaviors" because they all dealt with forms of classroom instruction.

Several conclusions are apparent from an examination of Table 10. First, an analysis of research needs based on the extent and impact of prior research yields different priorities than those gained through survey techniques. Only the elements of student attitudes and instructional resource exposure were included in the present study and in the majority of the other studies. Because of the overlap, it seems clear these two areas should become the focus of future efforts.

Second, survey needs assessment concentrates heavily on teachers, curriculum, and student cognitive development. This is not too surprising given that the survey respondents were predominantly teacher educators or teachers. These elements were not given high priority in my analysis because a great deal of work has already been done and the research to date has not been very promising.

Third, environmental influences (e.g., home, school, and classroom) are virtually ignored in the surveys as recent areas for research. Yet the research synthesis indicated quite promising effects for the limited work that has been done.

Fourth, career choices in science and science teaching were not ranked high in most of the surveys although teacher shortage concerns have grown rapidly in the past several years. Perhaps the dates of the surveys (1976-79) account for this, for in the late 1970's there was a great deal of rhetoric about teacher surplus.

Finally, four elements of the science education domain were not ranked highly in any of the studies; they were student skill outcomes, changes in teachers as a result of the teaching process, institutional change, and external intrusions.

The failure of the surveys to include research on the kinds of behaviors students exhibit during the learning process is not surprising given the paucity of prior research in this area. However, if one thinks of the students instead of the teachers as the primary actors in the learning process, then the study of appropriate behaviors (e.g., engaged time) seems highly desirable.

Research Recommendations

Based upon the needs assessment described above, and in spite of some contradictions with other priority studies, I would propose the following research questions as those most likely to help us take full advantage of renewed public interest in science education. I believe answers to these questions offer the most hope, at this time, for improving the teaching and learning of science.

- In what ways and to what extent do the environmental conditions of the home, school, and classroom influence science learning? The search for teacher and teaching effects on learning has not been fruitful. Other factors need to be explored, and environmental factors appear promising. The kind of research carried out by Coleman, Jencks, Walberg, and others should be applied to science learning so that we may identify the environmental factors that can be manipulated to enhance learning. Increased understanding of the influence of such variables as administrative support, community pressure, family encouragement, peer interaction, and class size would have tremendous policy implications for science instruction.

- How can student attitudes be measured more effectively and what factors determine these attitudes? Attitudes are important outcomes of science instruction and probably mediate learning and future intentions in science. Our current measuring techniques are limited, and we do not know what factors enhance or stifle desired attitude development.

- What are the barriers to and facilitators for providing students with the necessary exposure to instructional resources? This question is based on the assumption that students need to be exposed to science learning opportunities by enrolling in courses or participating in out-of-school activities. Science enrollments are low, and little is known about procedures for changing this. Furthermore, our understanding of informal science learning opportunities is minimal. To improve science learning, we need more students participating in more science learning activities. Research aimed at discovering ways to do this seems essential. Without students in classes, the best instruction in the world is for naught.

- What specific behaviors of students in classrooms are necessary for effective science learning? Past research has shown strong relationships between what students (not teachers) do and what they learn. Learning occurs in the learner because of behaviors the student exhibits (e.g., engaged time, attending, homework). Research on science instruction from the learner's perspective offers a promising line of investigation. Little is presently known and not much has been done except in the area of cognitive development. We need a better understanding of the student as a learner of science and the necessary behaviors to enhance that learning.

- What determines the science career choices of students and teachers and how can these decisions be influenced? Concerns about teacher shortages, science enrollments, the production of scientists, and general science literacy are all related to the increasing tendency of people to choose not to continue in science. Interest in and enthusiasm for science and its roles in a technologically oriented society have diminished in the past decade. Research is needed on the underlying causes of and ways to reverse the trend.

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## DISCUSSION OF SCIENCE EDUCATION

Rustum Roy, Chairman of the Science, Technology
and Society (STS) Program, Pennsylvania State University, and
Public Policy Fellow, Brookings Institution

Jim Conant, when he retired from Harvard, said that there is no point in worrying about the people who become scientists. They are so smart that they take it away from you even if you cannot give it to them.

I really come with an apology from the research community of the United States. That is my community. I am a research scientist, and I go out and do buck-hustling and do some research occasionally. In comparison to the community in Eastern Europe--the Soviets--we in the research community have shown by our behavior an extraordinary lack of concern not only for the whole process by which we generate our own kind but, much worse, for the Nation.

Yesterday, we were treated in the National Academy of Sciences to a perfect display of this. The only question was: "What money do I get?" Not "Is the national technology posture of the United States in a devastated condition?" But, "How is my budget increasing? What does the budget figure look like for my subfield?" So we are really part of the problem and not the solution.

However, I do some research in this field, as it so happens. My research in the science teaching business is concerned with the importation of science manpower to the United States. I will publish shortly a study to show that we have abstracted from the rest of the world the equivalent in contained technical training of about $980 billion between 1945 and 1983, or 1981, whatever the figure is.

In science teaching, who is our target? This morning you heard that approximately 1 percent of the United States population is involved in science and engineering. We draw that percentage, as (Wilson) Talley said, from about 2 percent of the population. The 99 percent...are we aiming at these people or are we aiming at the 1 percent in the new mathematics and science teaching emphasis?

In a technological democracy, the science research community thought they should erect a flagpole in the midst of the desert of culture: Here are our scientists; these are the only true citizens, and we should provide a few extras just in case we want some backup. This was the post-Sputnik approach to solving the problem, which was "make better scientists."

This is not the right goal for us now. I believe that we should now go after the pyramid model, which is what every other Nation does. If you give some science to everybody--a little more to this group, a little more to that group--you will have from the public, from the school boards, the money. We have to motivate the public. We have to do this kind of pyramidal basing of the motivation of students, of their parents, of the teachers, of the

Congress, and so on. And I suggest that in the middle of this, we would have a much more stable, democratic situation where an informed population would make more rational judgments.

We should aim the new mathematics and science at 99 percent of the population. This is a reverse of the Bible theory—don't go after the lost sheep; just worry about your major flock.

What content can possibly improve? Let me suggest that there is something here, and it is a critical element of my argument. What content can improve a lifelong motivation for learning about science and engineering? It is not enough to give it to them just for a few years.

Can we motivate people in those learning years? I say we can. I am saying that the answer is science, technology, and society. This, I claim, is the core of technological literacy. Now, here is my little motto for the day: Technology related to life is technology, science, and mathematics remembered for life. If you do not manage it in those school years, we will make illiterate citizens.

What I think was said this morning was that we should go from intuition to applied science to abstraction. Most of the people do it that way. I believe we should go from technology to applied science to abstract science. And in all our curriculum, we should reverse what we do—giving abstract principles. It is all very well but it simply does not work.

Now, what is "STS?" What am I talking about? What do I mean by science, technology, and society? I believe it is a perfect example of what was referred to as a mega-trend. There is no NSF program, there is no big deal, but all across the thousands of university campuses there has started on every single campus something in STS. There are courses and curricula. MIT has a college and all kinds of programs. There is already a kind of intellectual ferment, a democratic intellectual ferment, all across the land. STS gives us a starting base.

Let me quote for you the National Science Teachers Association (NSTA) policy statement. At the end it says:

> We believe that a minimum of 5 percent of science instruction should be devoted to science-related societal issues. In the middle of the junior year there should be 15 percent, in the senior year 20 percent.

This is not an idiosyncratic, self-serving view of the STS community. There are no tenure positions. This is really saying that this is something which ought to be national. And it is the NSTA saying this. It is their position.

If someone asks "What do you mean by STS?"—the easiest way to explain is to show them how to study science through "mineral resources," "population and health," "food," and "dental care." It is that kind of stuff to which you bring in science. It is not just saying: "I'm going to give you a little bit of stuff."

Let me make this point about modern glue. How can such a little subject make a difference? You go to the dime store and buy yourself a kit--those kits where you put the cars together--and outside the kit it says, "Glue not provided." What happens in our education is that we get all these chunks and no glue is provided, so you carry around these parts. I am saying to you that STS, if we design it right, can be the glue which makes the thing come together, a synthesis in a technological world of what we have and what we need.

On the new technology, I also have a word: We should not neglect the fact that technology does not equal the computer. There are many other technologies. Long before we get to the computer, you had better worry about the fact that the print materials are going out of style. There are not going to be any science textbooks. I had a publisher in my office yesterday say, "We are not going to publish any more science education materials." You say, "Who are you going to publish for? What are you going to do about print?"

In the STS field we have designed, with NSF support, new systems of free distribution, onsite reproduction. Print technologies are revolutionizing the process of distribution of materials. Not a word is being said. Everybody parrots that computer nonsense. I am not against computers. We are in that game. But video has not been anywhere near accurately used. I suggest that we appropriately use the new technologies.

So I bring words of hope and comfort and probably despair from one of those outsiders.

Comment: Dr. Lee Shulman

A comment about the glue, which I think is an extraordinary metaphor. There is not only an absence of the glue across these fields; there is an absence of the glue within.

Just a week ago I had finished a unit with our teacher education candidates, all of whom already have bachelor's degrees in the disciplines, on a concept that all of us remember from the 1960's called "the notion of structure in subject matter." And the notion was that there ought to be something that cumulates and develops as you teach a subject so that, for example, the last short story you teach in an English course is learned in a somewhat different way than the first short story, because a set of concepts and principles and procedures for analyzing these things have developed over the course of the year.

Similarly with a mathematics course...similarly with a science course. Because if you look at the interview studies of kids studying, for example, high school algebra, most of them have no idea of why the topics at the end of the year come then and the topics at the middle come then and the topics at the beginning come then. To most of the students, these are a disintegrated, arbitrary series of topics which they learn and pass the tests on because they are docile, and the consequence of not doing it is ending up at a less pretty campus when they go to college.

And as I made this argument, and I made it as passionately as I could, one of my students raised his hand--a Phi Beta Kappa graduate in mathematics from a major private university of the West Coast--and said: "How can I teach this to my high school students if I was never taught mathematics this way myself in the mathematics department of my university? And I'm considered one of the best students who has gone through that department in the last couple of years."

So I think that part of what I am saying is that we are depending right now on both the cross-disciplinary glue and the intradisciplinary glue emerging from the subject matter departments at our distinguished universities, usually in humanities and sciences. And that is not the way the subject matter is being taught to the future teachers or the future engineers.

I think that is a serious problem, and maybe at some point we ought to address it.

Robert Yager, Professor of Science Education,
University of Iowa, and
President, National Science Teachers Association

I did not know exactly what Dr. Roy would say, although we both had the benefit of reading Dr. Wayne Welch's very exhaustive and, I think, very fine paper in preparation for our discussant roles.

One of the things that I would quibble about is the setting that Wayne put science education in. And I think that Dr. Roy, without knowing, has come up with a perfect example of the direction and setting that I would like to have seen Wayne use.

I have no quibble with the domains. As a matter of fact, I think that is a beautiful way of analyzing where we are and what has been done. But it strikes me that one of the things that is missing is a look at what science education is in a more philosophical sense. And to me it is that discipline that is charged with looking at the interface between science and society. It is that discipline, then, concerned with how we can interpret for society what scientists do and what science is as...a basic enterprise of man. Similarly, it is interpreting for the scientific community the constraints of society and the interplay between the two.

It is that setting, when I read Wayne's paper and his look at the domains and the research that is being done, that concerned me a lot. In a sense, I see that my role may be tying Dr. Roy's comments and Wayne's paper a bit together.

The other point that I would pick at just a little bit--and I assumed that my role when asked to discuss the paper was to do a bit of picking and maybe to stir up a little excitement so the rest of you have a chance to react against what I might say or what Wayne has already said--is Wayne's deemphasis of goals in science education. If you noticed, this was on one of the charts, and Wayne did not think it was going to be worth too much.

That is an extremely important area, and, to me, it gets at why some of the other areas of research and some of the other things we have done have not been too fruitful. It seems to me that the domains chart and what we have done in science education is to assume that the discipline is one of studying what goes on in schools. We have defined it too much in terms of the one dimension of science, that is, the content dimension. And we have viewed our roles as simply ones of figuring out some way of taking this vast body of evergrowing knowledge and somehow getting kids, K-12 students, to absorb it. We have tested different ways of doing it, tried different techniques, different personalities of teachers, different kinds of curricular materials, but always with that fundamental goal. It is a matter of getting students to know more than the professional scientist thinks he or she knows.

It strikes me that this unidimensional view and definition of science is at the heart of and is the major problem.

Wayne has mentioned the Project Synthesis effort of which we were both a part. I think one of the striking results there was the lack of any philosophical perception on the part of teachers, except a commitment to the discipline, except to the content of science that the teacher knew and had experienced him or herself.

It seems to me that this lack of the philosophical perspective--a lack of any view as to what science teaching is about and what science education is about and what the fundamental mission of our discipline is--is a problem. Certainly the NSF status studies revealed that many teachers are able to voice goals, to state objectives, but most of the time when we tried to find examples of those stated philosophies and objectives in practice, there was nothing there. There was simply nothing beyond a commitment to imparting the knowledge that particular teacher knew or that appeared in a textbook.

I would look next at a few pieces of information that I think were missing from Wayne's analysis. It was mentioned this morning that there is a great mismatch between the science that is being taught and the science that is needed. Again, Dr. Roy touched upon that, I think very eloquently. I think it is fair to say that there is evidence in the status studies that the materials and the curriculum that are being used and being followed in classrooms across the Nation are perhaps appropriate, at best, for 95 percent of the students.

Another related problem is the fact that we have paid no attention to instructional theory. And again it is fair to say that there is a mismatch as far as what is being done--the strategies that are being followed--and what we know should take place. And this mismatch, too, could be labeled at 95 percent.

Many of you know that in the National Science Teachers Association (NSTA) we have been involved in a search for excellence, a search for examples of the exemplary or the desired or the ideal-state conditions that were identified by the Project Synthesis effort. As we have gone around visiting six centers of excellence, we have been amazed at the number of these programs for which there has been a concern for curriculum but practically no knowledge of and no interest in instruction. And we think this is a serious problem...again, a major mismatch.

Another point that I think is worth mentioning that came out of the synthesis effort, and mainly from the National Assessment of Educational Progress (NAEP) efforts, is that the longer a student stays in school, the less interest he or she displays in science. We think that this is of considerable importance. There is something about what we are doing that actually is causing the opposite kind of outcome than that we would like and expect in terms of interest. We found that the longer a student stays in school--and this, you will remember, is comparing 9-year-olds, 13-year-olds, and 17-year-olds--the less comfortable a student is with studying science.

Another effort deals with the emphasis upon literacy. You will note in Wayne's analysis that he put literacy at a moderate or low classification. Also, it seems to me that another important piece of research that deserves mention is the work of Miller and Volker. Their work, funded by NSF, deals with student attentiveness in science. In my mind I can accept their definition of attentiveness as really scientific literacy. For those of you who are familiar with that project, you know there were three elements of attentiveness or literacy. The first element was interest--expressed interest in science and technology. The report was that of typical high school graduates, 30 percent of whom expressed interest to the point of taking some action.

Another aspect of literacy, as they defined it, was knowledge, and they checked but four concepts across the high school years. One of those concepts was molecule. And they found that only 25 percent of the high school graduates had a working understanding of that concept. As I said, they looked at others. That is just one example.

The interesting factor about the finding for both interest and knowledge is that there was no increase in either across the high school years. That is, taking science did not increase knowledge and it did not increase interest.

The third aspect of attentiveness in science or, as I am calling it, literacy, was the ability to pursue knowledge, to increase knowledge, or to increase interest. And when that is taken into account, we find that the formula goes way down and there is way less than 20 percent that do anything about pursuing interest and/or knowledge.

When the three are put together, we find that only 10 percent of the American citizenry meets the criteria. And I think it is extremely important to say that we are doing something wrong if we have only 10 percent of our population, 10 percent of the high school graduates, able to meet this definition of literacy.

In summary, I would simply say, in terms of Wayne's paper, that I have no quarrel with the questions he has posed. I would be delighted to see those five questions as a research agenda. But I do have a problem with the setting he has proposed for science education. I do have a problem with the operational goals, the problems that have been identified if we were to use Lee Shulman's series this morning of troubles, puzzles, and problems. It seems to me we could be much more specific in terms of defining those if we could agree upon the fundamental goals of our discipline in an operational way.

I think there are problems in the way we have measured those, and we have had some confounding kinds of studies and reports. And I guess that is one of my concerns in some of the meta-analysis studies, although I must not get into that or I would be outweighed in a hurry in terms of what those studies do indicate.

It strikes me that the teacher studies that Wayne has pointed out have all the problems that he has identified. But the one, it seems to me, that has not been checked is that of philosophic orientation. Why is the science teacher there? What does the science teacher perceive his or her role to be? And it strikes me that most have a bad understanding of why they are there. And that singling out some of the exemplary teachers of exemplary programs indeed shows already, with our studies of the search for excellence, some fundamental differences among the teachers who are doing things and those who are just there.

It seems to me, then, that we need to define our problems, to prioritize our goals, and to proceed with attempts to solve our problems in a good procedure that we all follow in science. Too much of what is done in the research that has been reported and summarized, it seems to me, has been in the school environment only. And certainly the Volker-Miller study would suggest that the school is the least important element as an institution in being responsible for the understandings and the attitudes and the knowledge that the high school graduate has about science as a field.

Comment: Dr. Lee Shulman

Your reference to that study that purported to show that the more students studied science the less they liked it reminded me of the old suggestion that the best way to solve problems of overpopulation in some countries was to add sex to the formal curriculum and the kids would turn off on that, too.

I too, have some fairly serious quibbles with Wayne about his meta-analysis, especially with respect to teaching behavior, but I trust that Tom Good will handle that one in either his summation or his conference synthesis, with the elan I have learned to expect from Tom.

To reassure Wayne--there is far more research going on on student processes and student mediation of teaching than was referred to. And I think he is absolutely right: it has turned out to be a very productive area of research--not in science, though some in mathematics.

## OPEN DISCUSSION

DR. TALLEY: In discussing the effect of the environment, especially the home, you put it down as moderate and perhaps high. In 1977, Lucy Sells, in her doctoral thesis at the University of California at Berkeley, which was later simplified in an editorial in "Science," analyzed women who had the ability to go on in mathematics but did not. There are four ways you can group people. And the one that interested her was why women with the ability to go further did not do it. The dominant factor was the attitude in the home, especially of the mother, followed very closely by that of the father.

How many other studies have been done in this way, examining the cohorts of those who could do it but elected not to and trying to do a multiple variance analysis? I realize that the statistics show only associations and not causal relationships, but if I were to design a new curriculum, I would do it in a way to counter any negative influence--that this is not a ladylike thing to do, or that engineers do not get paid million-dollar salaries as do first basemen.

DR. ALDRIDGE: Wayne, I have read your paper. I have an advantage over the rest of the audience. In the figures you present on mean correlations and effect, you do not cite any errors nor do you indicate ways in which significant levels may have weighted the means. Are you satisfied that those have been done appropriately? And are these errors of sizes that you made ignored in presenting your table?

DR. WELCH: That's a good point, Bill. The series of papers that formed the basis for some of my data will be published in an issue (May 1983) of the Journal of Research in Science Teaching. And they do report standard errors for all of the effect sizes that they report or the mean correlations. The standard errors of the effect sizes are very much related to the number of studies, and I do not believe they included studies that had fewer than a sample size of seven. Most of them were in the range of 30 and above. The standard errors of the effect sizes range from perhaps 0.20 up to 0.90. So there is quite a range. And it is not clear to me that an effect size of 0.40 is a significant one given the probability of error that is included.

As far as the relative size of the sample, the people who develop analysis techniques examined that and found little relationship between the number of subjects in a given study and its influence on the overall effect size. There is some but it's not that large.

There is some concern and criticism about the use of meta-analysis--a process where you take a bunch of studies and try to come up with a single characteristic. And some people are philosophically opposed to that. I find it offers some insight, and I am not as concerned about it as some others are.

DR. SHULMAN: Let me make two comments on that. One is about the effect sizes and the choice of 0.40 as a cutoff point. My colleague at Stanford, Nate Gage, is concerned about how we in the social sciences may be using effect sizes that set a far higher standard for what is significant than some other fields may. And he did the following analysis.

Many of you who are readers of either Science or of good newspapers know that within the last half-year or so there was a large-scale experimental field study of the use of beta blockers in trying to prevent second heart attacks, I think it was, in people who had had an infarct for the first time. And a rather dramatic thing happened in this study. After something like the first or second year, it appeared that the results were so strikingly in favor of the experimental group that, on ethical grounds, the committee at NIH, I think it was, that was monitoring this study recommended that the study be terminated so that all people, including members of the control group, could have the benefit of these beta blockers.

What Nate Gage did, as professor of education at Stanford, was to get the data which were published on this study and to analyze the effect size, which is something that we who do educational research look at. Other folks do not tend to look at effect sizes.

The effect size (I believe, 0.14) that was represented by this difference was so striking in that case that they did something unheard of--they terminated the experiment in midstream.

We do make policy judgments in fields outside of education on the basis of what may, in the abstract, look like small effect sizes. These are complex issues and we do not really have that much time to go into them, but I think we have to look carefully at some of these methods and some of our criteria.

DR. SABAR: Wayne, I know you do not feel comfortable with some of the results. We have discussed it a little bit before. Yet I wonder what kind of message we give to teacher educators if we really have that little effect on teacher characteristics and teacher behaviors and if students' exposure to learning experiences seems to have a much stronger effect, especially in mathematics (0.70).

According to your report, the more students are exposed to science, their learning outcomes improve. We may get the wrong impression that just by being admitted to the course (is important). But is it not, really, because of the teacher's initiative in the classroom, because he or she really guides the students into time on task, into a certain kind of activity, or a certain kind of homework that you have been pointing out? And I am rather concerned about the message that we do have to say to teacher educators.

DR. WELCH: I am afraid I do not have a very good answer to your question. What I am trying to do is to sensitize those of us in science education to focus a little bit more on student behaviors and on some of the things that follow from that. One of the important characteristics of a science teacher is whatever it takes to sell his or her science course--to make it interesting enough that students will take more science in school, at the precollege level. That is where we need some research. Because I am not sure what it is exactly, what the barriers and facilitators are of getting into science classes.

Another line of research that I was struck with was presented at the conference we were at in Israel by both Susan Stodolsky and Dave Berliner. Berliner is trying to depict the teacher as an executive in a classroom who is responsible for managing the productivity of a number of people that he or she has responsibility for.

DR. SABAR: That is a behavior.

DR. WELCH: But it is a different kind of behavior than the sort of things that we have examined before. I do not know whether it will work. It does tend to increase the status, and it may be related in some way or another to the increased productivity of the classroom.

Some work that Stodolsky and Doyle did looked at the classroom...the student views, the ecological perspective, that classroom behavior is an exchange for some kind of reward, that you do things in class because of either the rewards you get through satisfaction or, more often, grades or something of that sort, such as you pay attention, you learn to use colleagues, you learn to understand what it is the teacher expects...things of that sort. And I think what is needed is research of that kind of student behavior that has implications for what teachers ought to do that enhances the effectiveness of the students' behaviors.

DR. LANIER (Judith Lanier, Michigan State University): Wayne, my question is related to the lack of a strong focus on your part on the studies of the cognitive processes of teachers and learners as they interact in the classroom. I was kind of struck by: "We have looked at teacher behavior that hasn't paid off, so now let's go to students and study student behavior."

So I am raising the question of whether you thought about cognitive processes and left it out, or whether it just was not represented in the past so therefore you left it out, or whether maybe I missed the applications of cognitive science and the studies of cognitive processing of teachers and learners in your presentation.

DR. WELCH: I thought about it. I was at a meeting in Pittsburgh just before Christmas related to needed research on cognitive processes and information science. What has happened in science education is that the research on teachers' cognitive processes is very extensive. I was not able to find in the sources which I used, which were research reviews (Project Synthesis, National Assessment, and the meta-analyses), anything that seemed to represent a large amount of research in that area.

The research on the cognitive development--Piaget, Ausabellian sorts of things, if those two go together--does not lend itself very well to the kind of meta-analysis work that was done. So one reason it is ignored is because it was not included.

It's the percent of people who can do certain tasks. It was included under the student characteristics. That is, the student characteristics are very much related to what students learn. And if you look at the ability to perform certain tasks and you develop some kind of a measure to measure that, it correlates around 0.4 to 0.5 with student achievement.

As far as gaps or promising future research on student characteristics, it seems to me that a lot has been done, and, except for some of the work that has recently been done by Larkin and others, I just do not know. It's sort of a void, an unknown, as to whether that holds promise or not.

DR. YAGER: I am somewhat perplexed with this kind of choosing up sides: "Is the student more important or the teacher?" I keep wanting to get back to what is the fundamental problem and what is it that we are after. And it strikes me too much, "Oh, I'm into teacher stuff, and therefore somebody is going to get money," or, "I want to study students."

It seems to me that that is where we need the philosophical orientation. We need to define the specific problem. And then maybe it would be obvious what we want to study or where we might go with what seems to me to be almost prejudices to a certain degree. It just strikes me that this sort of bantering is not getting us anyplace on any issue.

# SESSION IV
# MATHEMATICS EDUCATION

## TAKING MATHEMATICS TEACHING SERIOUSLY: REFLECTIONS ON THE TEACHER SHORTAGE

Jeremy Kilpatrick, Professor of Mathematics Education, University of Georgia*
and
James W. Wilson, Professor and Chairman, Department of Mathematics Education, University of Georgia*

The shortage of qualified mathematics teachers for America's classrooms is serious, and it will become more serious in the next few years. Planners, policymakers, and administrators must recognize the complex causes of the shortage, understand something of its historical roots, and see it more clearly as the surface manifestation of a far more intractable phenomenon.

Our thesis is that the current shortage of mathematics teachers is a symptom of a chronic and pervasive disease: the failure of various segments of society and the educational community to take seriously the teaching of mathematics. There has been a serious devaluation of mathematics teaching, and that is the malady underlying the shortage.

We are referring to attitudes toward mathematics, its teaching, and those who teach it. These attitudes are shared by students, parents, school administrators, members of the general public, State and Federal legislators, mathematicians, mathematics teachers themselves, and any of a number of other people who affect what goes on in mathematics classrooms. We claim that despite occasional professions of admiration for the heroic job that mathematics teachers do, too many people today have little regard for either the profession or the activity of mathematics teaching. Some who claim to value mathematics teaching most highly are those who, often in subtle ways, express the greatest contempt. The devaluation of mathematics teaching not only contributes to the teacher shortage but also operates to thwart attempts to relieve it.

The current shortage of mathematics teachers is most apparent in the secondary school. There one can identify clear expectations of a background in mathematics and pedagogy and can document that an insufficient number of people are available. In the elementary school, however, the shortage of trained teachers of mathematics is less obvious. Among the cadre of certified elementary school teachers, there are too few whose knowledge of mathematics

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is sufficient to the demands of today's curriculum--let alone tomorrow's--and who feel comfortable with mathematics. Schools face an especially severe shortage of teachers who are adequately prepared to deal with the unique concerns of mathematics teaching in the middle school years. Although our focus is the problem at the secondary school level, we feel strongly that there is a crisis in the teaching of mathematics at all levels.

In what follows, we look first at some ideas that have been proposed for alleviating the current shortage of mathematics teachers, examining what these ideas suggest about a more satisfactory approach to educational problems. Then we look at the school mathematics curriculum in the United States and the teacher's role in developing the curriculum. Next, we consider mathematics teaching in the United States and how it has been viewed by the participants in the process, as well as by outsiders. Finally, we outline some directions for improving mathematics teaching that are suggested by our observations. We believe there is a research agenda inherent in these observations.

## SOME IDEAS FOR REDUCING THE SHORTAGE OF MATHEMATICS TEACHERS

In examining various proposals for reducing the shortage of qualified teachers of mathematics, we have been struck by the frequent clash between short-term and long-term goals. Some proposals seem likely, if implemented, to exacerbate the problem of making mathematics teaching a profession that will attract and hold superior teachers in sufficient numbers to make future shortages unlikely. There is a very limited research literature on which to base projections of the costs and benefits of proposals. Research should be conducted into their possible effects, including any side effects, perhaps concurrent with their implementation.

### Raise Salaries for Mathematics Teachers

One line of argument says that if school mathematics teachers were paid more, there would be more candidates entering the field and fewer mathematics teachers would leave. The contention is probably valid and well worth pursuing. We have former students at every degree level who have abandoned mathematics teaching for higher paying jobs. Clearly, low salaries contribute in a major way to many teachers' decisions to leave the profession.

Nonetheless, people leave mathematics teaching for many reasons, and these should be studied. Serious study is also needed of the changes--both beneficial and harmful--in the profession that would be brought about by increased salaries. For example, although the benefits could include attracting to school mathematics teaching talented and committed people who might not have considered it otherwise, the costs might include attracting and holding more of the unqualified.

We do not oppose higher salaries for teachers, nor do we oppose paying mathematics teachers more than other teachers. As a short-term tactic, however, differential salaries possess some built-in assumptions and limitations.

- First, the tactic seems to assume that there are a substantial number of qualified mathematics teachers "out there" who, given enough pay, will stay in or return to teaching. The assumption is questionable.
- Second, differential salaries may adversely affect how mathematics teachers are distributed, with affluent school systems being able to exert even more leverage than they now do in attracting the best qualified teachers.
- Third, one must consider the divisive influence that differential pay might have on the profession. One group of teachers might be pitted against another. The Director of Teacher Education and Certification in the New York State Education Department, reacting to a plan for differential pay in that State, argued:

> Such a plan could possibly cause a major uprising among the 192,000 persons presently serving in the schools. That potential would result in more problems in New York State than any solution might be worth. (Gazzetta, 1982, p. 19)

## Provide Incentives to Preservice Teachers

Another popular proposal for dealing with the shortage of mathematics teachers is to provide grants or cancelable loans for students preparing to become mathematics teachers if they agree to teach mathematics for some specified minimum time. The long-term effects of this proposal may well be positive. Incentives--if handled properly--might encourage some talented young people to consider mathematics teaching, and one of the things we ask, as educators of mathematics teachers, is the opportunity to appeal to such students.

There is, of course, a negative side to any such incentive program--the likelihood of attracting to mathematics teaching people who are not interested in it as a career and who will teach only the minimum time needed to repay their obligation. Frankly, we have heard of no proposal in which the incentives were so high as to attract large numbers of such people. The positive and negative aspects of incentive programs now under way should be studied.

## Change the Requirements for Becoming a Mathematics Teacher

Some argue that the shortage of mathematics teachers is so severe that certification requirements should be changed so as to "free up" pools of talented people to teach mathematics. One of these pools consists of teachers from other subject fields who have not studied enough mathematics to qualify for certification as a mathematics teacher in a middle school or a high school. Many of these teachers are nevertheless assigned to teach mathematics, and some authorities have suggested that the shortage might easily be ended by providing these teachers with training in mathematics and then certifying them.

Our experience indicates that the suggestion is naive. Such teachers often have very weak preparation in mathematics and need extensive opportunities to develop a depth of mathematical knowledge and ability--whether measured by courses completed, competencies tested, or inservice programs survived. Few of these teachers, in our experience, have managed to develop and maintain a genuine commitment to mathematics teaching. Short-term programs that provide workshops, inservice courses, and the like almost always reflect a compromise in the quality and depth of mathematical knowledge that teachers are likely to need. A long-term side effect of this proposal might be the staffing of high school mathematics departments with underprepared, yet certified, teachers who would act as a barrier to the subsequent enlistment of better qualified and better prepared teachers.

A different compromise can be seen in proposals in Georgia and other States for a second level of certification for teachers of non-college-preparatory mathematics courses. The mathematics curriculum for students who are not bound for college is already a wasteland. It deserves the attention of fully trained and committed teachers. Study of the situation is needed, but in our view, teachers of non-college-bound students are likely to need a broader knowledge of mathematics and its applications than their colleagues who teach the college bound.

Another pool consists of scientists and engineers from industry and science-trained college graduates. These people may have adequate preparation in mathematics, but they do not have training or experience in teaching.

> Since most such recruits to teaching lack traditional teaching credentials, their work in a school system may create controversy. States should consider competency-based (rather than credit-hour-based) teacher certification; an alternative is to create a separate category, say, adjunct teacher, comparable to an adjunct professor in a university, for scientists who want to teach in schools but lack traditional certification. (National Academy, 1982, p. 18)

Yet another pool consists of students preparing for careers in business and industry who might be enticed into teaching. Gazzetta (1982) has proposed that business, industry, and education enter into a cooperative program in which capable high school students would enroll in collegiate programs preparing them to teach in elementary and secondary schools for 3 years. Business and industry would agree to employ the graduates of such programs during the summer and then would provide a stipend to enable the completion of a graduate degree in mathematics. After 3 years of teaching, the graduate would resign from the teaching position and join the sponsoring business or industry.

Most proposals to recruit teachers from nontraditional backgrounds assume that mathematics teaching requires a knowledge of either mathematics or teaching, but they fail to acknowledge that both are essential. These proposals also treat lightly the question of commitment to mathematics teaching as a profession.

## Provide Help in the Summer Months

For many mathematics teachers, summer employment has become an economic necessity. Unfortunately, such employment--like moonlighting--often has no relationship to mathematics teaching, and its value for professional growth is likely to be nil.

Some appealing proposals have been made to provide summer work in industries or in government laboratories where the teacher can be involved in applications of mathematics. Programs to implement such proposals, however, are rare and not well-known. The feasibility of the proposals should be explored and the programs studied for their value in professional development.

Another suggestion is that schools should employ some mathematics teachers for 11 months a year. The summer months could be used for the preparation of course material and syllabuses. Our experience with teachers who were hired during the summer to assist with the development of teaching materials indicates an added benefit of increased professionalism and a commitment to make the material work effectively in their classrooms.

A thread running through the proposals discussed so far for dealing with the shortage of qualified mathematics teachers is that <u>money</u> in the teacher's pocket is the key to any solution. Not everyone takes this view:

> Nonmonetary incentives include giving more support services to teachers, freeing them from noninstructional tasks, and recognizing outstanding performance....Some people think such incentives might be more important than added pay in retaining good teachers. (National Academy, 1982, p. 17)

Our view is that, important as additional funds may be in attracting and retaining qualified mathematics teachers, in the long run attitudes will prove more important than funds. That does not mean that salary is unimportant to teachers, but it does suggest that unless the teacher's commitment is appreciated and enhanced, rather than thwarted, monetary incentives will fail to stimulate superior teaching. Consider the following three pieces of information taken from surveys by the National Education Association (Editorial Projects in Education, 1982, pp. 245; 248):

1. The principal reason given by teachers for their decision to become a teacher was a desire to work with young people. This reason was given by over two-thirds of the teachers surveyed in 1971, 1976, and 1981.

2. The percentage of teachers planning to remain in teaching until eligible for retirement declined from 49 percent in 1976 to 35 percent in 1981.

3. The percentage of teachers responding that they certainly would enter teaching again declined from 53 percent in 1966 to 45 percent in 1971 and 38 percent in 1976, and then dropped to 22 percent in 1981.

It appears that the morale of teachers has declined faster than their relative purchasing power. If teachers are not permitted to work with young people in the ways they consider most appropriate without needless interference from authorities--and if other doors are open to them--they will not stay in the profession. The morale of mathematics teachers is not necessarily lower than that of other teachers, but for the qualified mathematics teacher doors have been opening to opportunities in business and industry.

The solution to the shortage of mathematics teachers is not just more money--even though more money is needed for education and some parts of the solution may cost a lot of money. The solution requires that more students be recruited to the profession, that competent qualified teachers be retained in the profession, and that incompetent or underqualified teachers either be helped to improve in quality or be helped out of the profession. A condition of this solution is that the profession itself must become more attractive in the rewards it offers.

## HOW DO WE APPROACH EDUCATIONAL PROBLEMS?

An important observation about the various proposals for reducing the shortage of mathematics teachers is that these proposals have not come from the teachers themselves. They have come from members of various groups who manifest a concern for the plight of the classroom teacher but who are not themselves engaged in teaching. Even the various professional associations that profess to speak for the mathematics teacher seldom count more than a handful of practicing teachers among their leadership and have only a fraction of the practicing mathematics teachers among their membership.

Educational problems in this country generally have been approached in a top-down fashion, often with little effort to find out what the problem looks like from below--the classroom, in this case. One of the difficulties we all face in addressing problems related to the teaching of mathematics is that most of us who wrestle publicly with the problems have not been in many classrooms lately. We have not walked in the shoes of the mathematics teacher who has five classes (and three "preparations") a day.

Hear the voice of a second grade teacher as she expresses her frustration at yet another newspaper column on mediocrity in education:

> I feel an unrelenting need to express myself regarding the negative feelings surrounding public education and the fact that the classroom teacher is rarely the decision maker, the one person who is in the position of having real insight into children and the education process....

> Mediocrity comes from the feeling of impotence in a mass of others who are making decisions which affect the classroom teacher: legislators, university professors and researchers, boards of education, administrators, curriculum directors, parents, etc., leaving the classroom teacher at the bottom of a pit surrounded by the decision makers pointing their fingers and saying (in many different ways) "Do it my way." Should the teacher be able to make sense of all of that melee, a new bandwagon will come by for the decision makers to attach themselves to, and so new directions are shouted into the pit....
>
> The lack of concrete support, diminished morale, mixed messages, the feeling that "I must not be good enough to take responsibility for the education of my students," and the feeling that one is, at times, a puppet, victimizes the child. For we know in our professional hearts what kind of environment a child needs in which to grow and learn and "find that knowledge that is within," but I can assure you that a negative working environment caused by society's demoralizing attacks on schools can affect the child....
>
> Excellence in education will occur more frequently when the teacher becomes autonomous and is made responsible for the education of students. Excellence will occur when a public school teacher's status is raised to that of a professional with the salary and esteem equal to other professions. Excellence will occur when we cease looking at education as "meeting minimum competencies." Excellence will occur when teacher training institutions cease looking so strongly at teaching styles, techniques, philosophical stances, and the ability to expound educational jargon, and take a closer look at necessary personality traits: an aura of confidence; of being turned on to life; of having the ability to empathize with a child; of being secure enough in the assessment of a child's emotional and academic needs to meet anxious parents and administrators calmly; of being secure enough to be first and foremost, the child's advocate.
>
> The teacher is the clue, the catalyst, the core around which all else flows. We need to begin there. (Ginn, 1983, p. 6).

That voice should haunt anyone who addresses the issue of improving the teaching of mathematics in our schools. We do not presume to speak for the teachers themselves. But we do wish to bring forward certain considerations that have occurred to us as we have thought about the problem and as we have talked to teachers.

## THE SCHOOL MATHEMATICS CURRICULUM IN THE UNITED STATES

### What the Curriculum Has Been

Throughout this century, as the school mathematics curriculum has been pulled to and fro by various groups--educational psychologists, mathematicians, mathematics educators, school administrators, admissions test developers, curriculum theorists, school boards, public interest groups, bureaucrats, teachers' associations--the teacher of mathematics has tended to be ignored, or worse, given a token hearing.

Sixty years ago, the National Committee on Mathematical Requirements of the Mathematical Association of America issued a report on The Reorganization of Mathematics in Secondary Education (1923), which was meant as a reply to the education generalists who argued that mathematics, like any other school subject, had to have "social utility." This confrontation between generalist and specialist joined the issues of mathematics for everyone and mathematics for the few. Forced to defend its place in the curriculum, mathematics seemed unable to justify its value beyond the most trivial forms of arithmetic, algebra, and geometry, and accordingly declined in the school curriculum during the thirties and forties.

By the mid-1950's, school mathematics was again on the defensive--this time against back-to-the-basics educators who, appalled at the inroads that progressive education had made in the schools, wanted to recapture a mythical past when everyone could calculate cube roots and divide polynomials with ease. Into this fray, but ignoring both sides, stepped the mathematicians, bringing the "new math." They brought many positive forces to mathematics teaching, but they did not manage to get teachers to work with them as colleagues and equals. As so often happens, teachers were treated "with the kind of casual arrogance only professors can manage, when they conceive of the lower schools" (Schaefer, 1967, p. 51), and this treatment may have been the Achilles' heel of the new math movement.

The popular view these days is that the new math failed. A more considered view, and one that is shared by a good many people who have sought to analyze this curriculum reform effort, is that the new math was never really tried--in the sense that it did not permeate most classrooms very far. Referring to the curriculum innovation associated with the new math, the report of the National Advisory Committee on Mathematical Education (1975) concluded: "The principal thrust of change in school mathematics remains fundamentally sound, though actual impact has been modest relative to expectations" (p. 21). The popular perception, however, seems to be that the change was massive and that it has now been repudiated.

Partly because of the perception of the new math as a failure, the 1970's produced another back-to-basics movement. Many schools had never been away. The result was a trivialization of textbook content, a flood of duplicator worksheets, and much hand wringing when, at the end of the decade, the National Assessment results showed that many students were unable to use mathematics for solving simple problems (Carpenter et al., 1981).

A recent turning point in the tug and pull of the school mathematics curriculum seems to have been the Agenda for Action of the National Council of Teachers of Mathematics (1980). This report, which reflected an input by mathematics teachers, presented recommendations for school mathematics in the 1980's. The report set an agenda rather than providing a blueprint.

The recommendations in the Agenda called for an emphasis on problem solving and applications; a reexamination of basic skills, incorporating calculators, computers, and other technology into the mathematics curriculum and mathematics teaching; and more mathematics for all students. The recommendations have been criticized, applauded, widely cited, and widely ignored. Textbook publishers have indicated that they are incorporating the recommendations into their material, but the textbooks look much the same as before. For the most part, classrooms continue in a drill-and-practice mode.

We follow the Agenda in believing that the impact of computers will change mathematics teaching, the school mathematics curriculum, and teacher preparation programs. We too would applaud genuine problem solving by students. We endorse the recommendation that every high school graduate should have 3 years of appropriate high school mathematics. But we further believe that the mechanisms to bring these changes about do not exist independent of competent, highly trained mathematics teachers. The arena for action is the classroom--not the superintendent's office, not the bureaucrat's office, not the mathematician's office, and not the speaker's platform.

The corollary to these comments is that if the mathematics curriculum changes as proposed through the 1980's, the need for competent mathematics teachers will become more desperate. More teachers will be needed, they will need more and better training, and many teachers in the field will need advanced training and, perhaps, retraining. In short, what is now a serious shortage may soon become critical.

## How the Curriculum Has Been Seen

Mathematics has traditionally played a key role in deciding who would be allowed to continue in the educational system and obtain the benefits society offers the educated. Even before mathematics was identified as the "critical filter" (Sells, 1976) in determining entry into college majors leading to scientific and technical professions, achievement in mathematics had been well established as an indicator of fitness for higher education. In countries such as France and Israel, mathematics maintains its status as the gatekeeper to higher education. Here in the United States, its role may be less prominent, but it still shows up in entrance requirements for college. For example, half of the Scholastic Aptitude Test is devoted to the assessment of mathematical abilities that candidates have developed during their school years.

At least in part because mathematics is seen as a necessary evil by most students, and perhaps by many teachers, mathematics classes have a sameness that can be stifling. Boredom seems to be accepted as an inevitable accompaniment to the mathematics experience in school. As an observer noted in a case study of a U.S. public high school in 1976:

> A [illegible]ment about math classes is that they were dul[illegible]was perceived as being more fun...I got the imp[illegible] students looked forward to science but no one [illegible]ok forward to math. (Quoted in Fey, 197[illegible]

School ma[illegible]as two faces. To the mathematics educator and to many mathematician[illegible]bject is challenging and potentially exciting. It offers many a[illegible]oblem solving, pattern finding, exploration, proof, estimation, c[illegible], applications to other fields, and opportunities to demonstrate [illegible]d to develop intuition. It has many parts, including statistics, [illegible]ometries, algebra, number theory, combinatorics, probability, [illegible]metic. To other educators and to the general public (and perhaps [illegible] teachers of mathematics), school mathematics is viewed in terms of the abil[illegible] to perform paper-and-pencil computations with whole numbers, fractions, and decimals, plus some skill in manipulating algebraic expressions and some knowledge of elementary concepts of geometry and measurement. Many people might define the mathematics curriculum that way--it expresses what they think any high school graduate should know of mathematics. Such a definition, however, misses much of what the school mathematics curriculum might be.

## The Teacher's Role in Curriculum Change

When people discuss the failure of various curriculum development projects to have made much of an impact on mathematics teaching, they may point out that the teacher is constrained by various conditions that put limits on change. They seldom--in this country, at least--talk about enlisting the teacher in curriculum development.

American mathematics educators tend to disparage grassroots efforts to improve the school mathematics curriculum. One hears scornful comments about "reinventing the wheel," or, as someone has said, "reinventing the flat tire." Instead, instructional theorists and curriculum developers tend to look for some way to get around the teacher and to provide an instructional package that does it all: a <u>teacher-proof</u> curriculum.

It is disturbing that educational theorists have promoted this view, and even more disturbing that so many mathematics teachers have eagerly accepted it. The teacher-proof curriculum idea is, after all, built on the notion that the main thing wrong with current approaches is the presence of a teacher to misunderstand, distort, and subvert the instructional process.

Why have teachers accepted the idea that they are incapable of taking part in the curriculum development process? Lortie (1975) has argued that the system for recruiting entrants into the profession tends to select people who are conservatively inclined and who are unlikely to be interested in investing the effort needed to change the circumstances of teaching. Teachers tend to resist change, in Lortie's view, because of who they are and how they have been recruited into teaching.

But does that explain teachers' reluctance to participate in curriculum change? Let us examine the prevailing myths about the teacher's role in curriculum development in three different countries: Sweden, England, and the United States. To call these conceptions "myths" is not to put them down or to say they have no basis in fact. It is rather to emphasize the function of these conceptions, whether or not they correspond to reality, in guiding people's actions.

Sweden has a highly centralized system of education, and the Swedish myth is that the government should set the framework for curriculum development, as for other educational matters. Teachers in Sweden actually welcome the active role of the central government in taking the initiative in educational innovation (Dalin, 1973, p. 245). The politicians set the broad aims for education in Sweden, and it seems reasonable to most educators there that the central administration, with its greater resources for research and development, should have the responsibility for directing reform. Consequently, it would be unthinkable for a teacher or group of teachers in Sweden to initiate any innovation that did not conform to the nationally prescribed curriculum. This is not to say that local initiatives have not been successfully attempted or that all teachers accept central direction passively, but only that the myth of teacher deference to central decisions guides Swedish educational thinking.

England has a different educational tradition and a different myth. The English subscribe to the myth that the teacher is responsible for determining the curriculum. As Maclure (1972) has noted:

> [This is a myth] in the sense that it expresses great truths in a form which corresponds more to an idea than to reality. The less factually correct it may be, the more important it is to assert....To refer to this as a myth is not to denigrate it. It is a crucial element in the English educational idea. It is the key to the combination of pedagogic, political and administrative initiatives which provide the drive for curriculum reform in England and Wales. (p. 41)

One can see the myth operating in the English invention of teacher centers and in the major role teachers have played in most English curriculum development projects. The English attitude toward curriculum reform is very different from the American attitude.

What is the American myth about the teacher's role in developing the curriculum? Traditionally, it has been that the local community is the determiner of the curriculum. We have given considerable power to local school boards, acting outside the profession and for the community, to determine what shall be taught in school. There is merit in this approach.

Mark Twain was not completely correct when he observed:

> In the first place God made idiots. This was for practice. Then He made School Boards. (DeVoto, 1946, p. 567)

Local boards have been given responsibility for curriculum policy, and local teachers are expected to work up alternatives for board decision and work out details once policy decisions have been made.

But the traditional myth of local determination of curriculum seems to be crumbling. A major reason is the mobility of our society. When parents move from one place to another, they expect their children to study much the same mathematics in the new school that they did in the old one. Mathematics, people believe, is a subject with a strong partial ordering, if not a linear ordering. If you miss out on some mathematics in the sequence, you will never catch up--now there is a myth we all understand. Our system of Carnegie units, our national tests for college admissions, our textbook publishers seeking national sales--all conspire to make the school mathematics curriculum a bland concoction, relatively uniform across communities and highly resistant to change. Add to this the growing desire to State departments of education to ensure minimum standards, and one has the local school--and the teacher--caught in a web of constraint.

Curriculum development projects in the United States over the past two decades have helped to break down the myth of home rule in curriculum, the idea that children differ so much in abilities and needs from place to place that only the local schools know them well enough to devise an appropriate curriculum for them. As Ovsiew (1973) noted, the curriculum development projects of the 1950's and 1960's proceeded on the basis of a completely different assumption; namely:

> [that it would be worthwhile to spend] millions of dollars, using the very finest scholars, and paying for research, field test and development to create curricula that could be used in thousands of school districts, rather than spend hundreds of dollars using teachers to make curricula to be used in one school district. (p. 530)

The sentiment is familiar, and one accepts it: Who could be against efficiency and economy in curriculum development? One should realize, however, what this myth is saying about the teacher's role: Teachers may be allowed to participate in curriculum projects, but they should understand their place. They are helpers or guinea pigs, not true collaborators. The teacher's role is to be a consumer of the finished curriculum that someone else has developed someplace else.

## How the School Mathematics Curriculum Should Be Seen

Assessing the curriculum reform activities of the School Mathematics Study Group (SMSG)--the best known, and probably the largest, curriculum development of the new math era--its director, Ed Begle (1970, p. 27), argued that SMSG had helped to bring under control the problem of teaching better mathematics. Not under control, and open to research, was the problem of teaching mathematics better. Although Begle accurately perceived the challenge of the two problems, he was overoptimistic in his assessment. One of the clearest lessons of the curriculum reform efforts of the sixties and seventies was that although there are many barriers to curriculum innovation, pressures for change will always be present (Howson et al., 1981, chapter 1). The process of curriculum change needs to be both continuous and continual.

A more important lesson, but one that perhaps has not been well learned, is that the teacher is the focal point for any change in the school mathematics curriculum.

> There is one thing that distinguishes teaching from all other professions, except perhaps the Church--no change in practice, no change in the curriculum has any meaning unless the teacher understands it and accepts it. This is a simple but fundamental truth that no curriculum builder can ever afford to forget. If a young doctor gives an injection under instruction, or if an architect as a member of a team designs a roof truss, the efficiency of the injection or the strength of the roof does not depend on his faith in the formula he has used. With the teacher it does. If he does not understand the new method, or if he refuses to accept it other than superficially, instructions are of no avail. At the best, he will go on doing in effect what he has always done, and at the worst he will produce some travesty of modern teaching. (Beeby, 1970, p. 46)

Our contention is that the teacher must not only understand and accept proposals for curriculum change, but that he or she also needs to be educated to participate in the process, should be expected to participate, and should expect to participate. Part of the professional development of mathematics teachers should be training and apprenticeship in curriculum work. It would be unrealistic to expect that all curriculum materials will be designed by teachers or that all teachers will choose to participate in designing them. But as many teachers as possible should be made to feel part of the process, and all should feel an obligation to adapt curriculum material to their situation.

> Curriculum development will have to coexist with 'non-participant' teachers: but the latter will still have a vital contribution to make providing they are familiar with the significance and the workings of innovation. The lessons of the reform period we have recently witnessed are that most attempts to enforce radical changes in practice have been subject to trouble and distortion and then only rarely have original intentions been realized. If innovation is to proceed more satisfactorily in the future then, it is essential that we ensure better understanding and acceptance by teachers. Consequently, one of the most significant tasks for future work in the field of curriculum development is to broaden the base of innovation. (Howson et al., 1981, p. 265)

## MATHEMATICS TEACHING IN THE UNITED STATES

### What Mathematics Teaching Has Been

Who Are the Teachers? Teaching historically has been one of the most open of professions, providing an avenue for talented people to raise their status in society when other avenues were closed to them. Until recently, women and minority group members who were gifted in mathematics went into mathematics teaching because other opportunities were not available. That situation has changed. Students entering college today find that a sound preparation in mathematics allows them to choose among many attractive undergraduate majors, and students graduating from college today with a major in mathematics or computer science find inviting career opportunities competing with teaching for their attention.

Over the past 15 years, the number of women preparing for secondary mathematics teaching at the University of Georgia has declined. In 1970, approximately 80 percent of our prospective secondary mathematics teachers were women. The decline in the teacher candidate population seems largely attributable to a decline in the number of women enrolling in the program. The reason, we believe, is that many other career options are now open to women who have talent in mathematics.

As we recruit young people to consider mathematics teaching as a career, we want to draw from the same talent pool as the fields of engineering, computer science, and mathematics. The demands of mathematics teaching call for the same range of talent as such fields; we cannot accept the demeaning notion that only the less talented are fit to teach. As mathematics educators, we want to tell our story of mathematics teaching as a challenging and rewarding career to the whole range of students with mathematical talent.

What Has Teacher Education Been Like? Mathematics teaching has been approached somewhat differently in the elementary grades than in the secondary grades if only because elementary school teachers historically have been generalists educated in teachers colleges, whereas secondary school teachers have been, whenever possible, university graduates with the equivalent of a major in mathematics plus preparation in pedagogy. Of course, these have been the expectations, not necessarily the reality.

In colonial America, it was an exceptional grammar school teacher who knew "fractions" and "the rule of three" (Cajori, 1890, p. 9). The introduction of certification requirements in the latter part of the nineteenth century substantially increased the amount of college training required to teach in an elementary school. Yet by 1960, the mathematics education of a typical graduate of a 4-year certification program consisted of 2 years of high school mathematics, one course in general mathematics, and a course in methods of teaching mathematics. The median number of semester hours of mathematics required to teach in high school was 15, and a survey of high school mathematics teachers in 1959 found that 7 percent had taken no college mathematics and only 61 percent had studied calculus or more advanced courses (Gibb et al., 1970).

Given only a limited amount of time in which to prepare teachers, and recognizing that the conditions of teaching have become much more demanding, mathematics educators have been increasingly concerned with equipping the preservice teacher to survive the first year on the job. By arranging for the preservice teacher to get out into schools and by providing courses that are aimed at the practical concerns of teaching, they quite naturally hope to make the teacher training program as relevant as possible. Such moves have generally been applauded by preservice teachers.

An orientation toward practicality in teacher education has much to recommend it--there is little point to a program whose graduates lack the skill needed to keep order in the classroom and to manage their other responsibilities as teachers. One should note, however, that a view is likely to be perpetuated in which subject matter is dealt with in terms of concepts and teaching in terms of "skills."

The shift to a survival orientation has meant that teachers enter the classroom without much preparation for a career in teaching. They may be equipped to use the textbooks they are given, but they are not equipped to develop curriculum units of their own. They may know how to follow the syllabus for a geometry course, but they have not thought about alternative ways that geometry might be integrated into the curriculum. They know about the content of the courses in the grades they teach, but they are not familiar with--and may not consider it their business to know about--the mathematics taught in other grades or in other school subjects. In short, they have not been educated to be mathematics educators.

<u>What Has the Teacher's Professional Life Been Like?</u> It is commonplace to ask why the schools cannot be run like businesses or industries. They are. In fact, the false equation between educating a child and manufacturing a product is the source of many of our difficulties in education. It has led too many people to conceive of teachers as educational technicians rather than as autonomous professionals or educational leaders.

This model--coupled with textbook material that dominates how classes are organized, mandated assessments that lock instruction into a straightjacket, and peers who bring heavy sanctions down on the head of the innovator--has brought a stultifying sameness to mathematics classrooms and a diminished sense of importance to mathematics teachers. Further, a key person in the professional life of the teacher--the building principal--has too seldom been an instructional leader who works with teachers as colleagues. Principals, too, have bought the managerial model.

A key to the "image problems" that teaching has contended with in recent years--"burnout," defections into other fields, vanishing enrollments in teacher education programs--may lie in the close look that every student gets at teaching before deciding whether to enter it as a profession. Not only has that close look revealed a beleagured soul, asked to do too much and given too little with which to do it, but also the messages from society to the student have suggested that teachers may not have the answers, and certainly do not have the authority, to act as they once did.

Proposals to "deschool" society and to free children from oppression, though they may have little visible impact on how society manages its schools, communicate to students a diminished view of the teacher's importance. As the rights of students have quite properly been asserted, there has been a price paid in the quality of the relationship between student and teacher. As society, through its boards of education and State departments of education, has moved to ensure that the quality of education is improved, the teacher has been caught in the middle: forced to give classroom time to preparation for and the administration of tests, compelled to fill out more paperwork, and obligated to face students and parents whose stereotype of the teacher is increasingly that of an incompetent, powerless, poorly qualified, low-status person.

Many teachers today find it difficult to maintain the sense of service and mission that historically has enabled teachers to put up with adverse circumstances of all sorts. A series of research studies sponsored by the National Science Foundation provide a view of the classroom from the teacher's perspective (Fey, 1979a, 1979b):

> "...I've had a lot of spark taken out of me in the last two years. We hear administrators talking about meeting the needs of students--individualization. But we never get time off to develop these things or the financial support....I've talked to them about getting materials and they say that materials aren't as important as the student-teacher relationship. But I find it very difficult to stand up and play Johnny Carson everyday."
>
> "I always thought that the main goal of education was teaching kids, now I find out that the main goal is management."
>
> "We need to be working with teachers, not checking on them....Education is generally a negative enterprise toward children, toward teachers. It is a highly structured reward structure which emphasizes the negative. Those who get rewarded are those who make the fewest mistakes." (quoted in Fey, 1979b, p. 499)

As Harold Taylor (1982), high school teacher of mathematics in California and a director of the National Council of Teachers of Mathematics, said last year in his testimony to the National Commission on Excellence in Education: "Teachers feel they are neither respected nor appreciated. In such a setting of frustration and unhappiness, mathematics education cannot attain excellence" (p. 3).

## What Mathematics Teaching Needs to Become

> We live in a complex, dangerous, and fascinating world. Science has played a role in creating the dangers, and one hopes that it will aid in creating ways of dealing with

> these dangers. But more of these problems cannot, and will not, be dealt with by scientists alone. We need all the help we can get, and this help has got to come from a scientifically literate general public. Ignorance of science and technology is becoming the ultimate self-indulgent luxury. (Bernstein, 1982/83)

We in the United States need a renewed commitment to the learning of mathematics--and therefore to its teaching--not because we need to "catch up" as a Nation with the Russians, the Japanese, and the Germans or because test scores have fallen and our pride is hurt, but because the quality of the future lives of our citizens depends on whether or not they have the mathematical tools for thinking about problems that confront them individually and collectively. As we work toward creating this commitment, we need to recognize that no quick-fix "solution" to the shortage of qualified teachers of mathematics, however effective it might be in placing people in classrooms, can accomplish the transformation required in what it means to teach mathematics as an activity and a career.

The image of mathematics teaching must be changed, and the only honest way to do that is to change the substance as well. The transformation of mathematics teaching must ultimately become a cooperative effort in which all segments of society--pupils, teachers, parents, administrators, school boards, textbook publishers, the general public, and people at all levels of government--work together to make teaching in general, and mathematics teaching in particular, a more rewarding enterprise for all concerned.

Without an expressed national policy on education in mathematics, Americans work within the framework of a tacit policy that views school mathematics largely in terms of its power to help identify and prepare students for positions in the labor force (Spring, 1976), and not in terms of its other powers and values. When the educational system does not appear to be functioning as it should, people tend to think of solutions in manpower terms. Having long ago adopted a business/industry metaphor for thinking about educational problems (Callahan, 1962), we are inclined to think in terms of "managing" change in the schools and imposing top-down structural reorganizations. But just as we may be learning some lessons in our large corporations about how to improve working conditions by giving workers a larger emotional and intellectual stake in their work, so we may need to learn some similar lessons for dealing with teachers and the conditions of their work.

Proposals for change in education come thick and fast these days, yet there seems to be no independent or quasi-independent agency to analyze their merit. An agency that is as free as possible from shifting political winds and entrenched bureaucratic obstacles is needed to conduct policy research in education. In examining proposals to deal with current and future shortages of mathematics teachers, for example, such an agency would be able to enlist the cooperation of teachers (those in training, those now teaching, those thinking of leaving, those who have left) in studying the problem, rather than relying on the secondhand views of experts and officials as voiced through committee hearings, commissioned papers, and conferences. An agency insulated from the various vested interests in mathematics education, our own included, could study the proposals in the light of their short- and long-term effects, and not simply in terms of their political feasibility.

Recruitment and Retention. The emphasis in this discussion on the need to change the circumstances and conditions of school mathematics teaching in the United States today should in no way be interpreted as a denial of the importance of improving salaries in the profession. We wish to underscore our endorsement of attempts to raise those salaries to a level that will attract and keep talented teachers. When we say that higher salaries are not sufficient to solve the root problem of failing to take mathematics teaching seriously, we do not mean to imply that higher salaries are unnecessary.

Whatever is done to retain or retrain mathematics teachers, the long-term solution to the crisis in mathematics teaching calls for a continuous supply of young, talented people entering the field. We view the dramatic decline in the number of entrants to mathematics teaching as a far more serious problem than any acceleration in the rate at which teachers are leaving. Teaching has not been attracting enough capable young people. Lortie (1975, pp. 86-87) reports that the majority of male beginning teachers have no intention of staying in classroom teaching for their entire career and that the majority of women beginning teachers expect to leave the classroom within 5 years, although most expect to return after raising children. "In some fields the beginner may start at a relatively low income but, with success move into a series of significantly higher earning positions" (Lortie, 1975, p. 82). Such positions differ in status, and such occupations may be termed "staged." As Lortie observes, "classroom teaching is notably unstaged" (p. 82).

One role that research might play in addressing the long-term problem of improving teaching is to explore the effectiveness of various ways of making classroom teaching more staged. A concept that had been proposed recently is that of "Certified Master Teacher"--analogous to Certified Public Accountant--to be awarded to teachers who have passed a rigorous examination. Not only are there policy implications of such a move that require systematic study, but there are also opportunities for inquiry into the knowledge and skill possessed by the most talented members of the profession, as well as the levels of knowledge and skill deemed important by various constituencies, to provide a foundation for the construction of comprehensive examinations.

Researchers might also examine systematically various programs that appear to be attracting and retaining talented teachers of mathematics. What are factors that influence such teachers to enter and remain in the profession? What factors influence them to leave? What role does the school administration--the principal, in particular--play in retention? What role do a teacher's peers play in a decision to leave mathematics teaching?

Education and Professional Development. Another issue concerning the long-term health of mathematics teaching is the nature of the training that teachers receive. Some institutions are finding that, paradoxically, adding a fifth year to a 4-year preservice teacher education program attracts rather than scares off bright students (Benderson, 1982). Apparently, such students value a program that might offer them a higher level of preparation for teaching. The challenge to mathematics educators, then, is to design programs that will offer a higher level of preparation. That challenge is accentuated by the need to anticipate in those programs how computers will change both the content and the pedagogy of school mathematics.

The preparation of teachers of mathematics requires a knowledge of both mathematics and pedagogy, but few people have ever been satisfied with the balance between the two or with the extent of either. The level of preparation now is probably as high as it has ever been, but expectations have risen and so the level is perceived as being lower than it should be. In asking that the quality of preparation be improved, one should not make the mistake of pitting subject matter against pedagogy; they "are inextricably intertwined and should always be thought about that way. The highly polarized argument that sets courses in teaching against courses in the disciplines is overdone on both sides" (Howe, 1982, p. 28).

Test score evidence indicates that, on the average, education as a college major does not attract students of high academic ability. It is not clear whether the relative deficit in academic ability is greater in mathematics education than in other fields of education. It would be helpful to have more information on programs and activities that have been successful in recruiting and preparing students who are strong in mathematical abilities and commitment to teaching. At a recent conference on teacher education, someone suggested that education need not draw the most talented students, implying that such students would quickly become disenchanted with school teaching. It that what people want for the profession?

In seeking to relieve a teacher shortage, policymakers and administrators should not make the error of assuming that everyone currently teaching mathematics should be retained there at all costs. On the contrary, one means of demonstrating a seriousness about mathematics teaching would be to find mechanisms to assist the less competent and the uncommitted to leave teaching for other pastures. One test of a profession's vitality is how it deals with dead wood.

The Mathematics Teacher As Curriculum Developer, Researcher, and Mathematician. The professional life of mathematics teachers needs to become more rewarding. Again, perhaps paradoxically, that might be done by expecting teachers to do more--not more paperwork or test administration, but expecting, and assisting, the mathematics teacher to be a developer of curriculum, a researcher, and a mathematician.

Earlier in our discussion, we addressed the prevailing mythology in the United States that teachers are not viewed, and do not view themselves, as curriculum developers. We were not contending that no teachers in this country are doing curriculum development work. We know of several instances in which they are, but we do not know of any research on the extent and effects of such activities. Teacher centers of various types offer a vehicle for curriculum development work, and one can envision summer institutes--patterned perhaps after the National Science Foundation Institutes of two decades ago--in which mathematics teachers would get training and assistance in initiating the collaborative work needed to transform the current school mathematics curriculum.

A special need is for curriculum material to accompany and support the growing presence of microcomputers in mathematics classrooms. If computers are to be incorporated into mathematics instruction in more than a superficial way, mathematics teachers will have to devise instructional material that they themselves can use.

Teachers also need to become collaborators in research:

> Research in mathematics education has increasingly been moving out into the classroom. This has been, in general, a healthy move. It would be better, however, if teachers were working more closely with researchers in formulating their problems and interpreting their findings and not simply in helping them gather data. The teachers would benefit, with respect to both their professional attitudes and their effectiveness, and so would the researchers. (Kilpatrick, 1981, p. 27)

Just as important, the teacher needs to be a mathematician:

> Too few teachers are members of the mathematical community, even in the definable sense of being members of professional associations of mathematicians....It is distressing how many [teachers] say, "Of course, I am not a mathematician." It is surely not reasonable to teach swimming and not be a swimmer, or a language and not be able to speak it. Why then is it reasonable to teach mathematics and not be a mathematician? (Fletcher, 1975, p. 212)

Fletcher argues that the coming of the computer has changed the mathematics community so that it is no longer composed primarily of teachers and that schoolteachers need to be acquainted with how other mathematicians today use mathematics. He cites programs in England in which teachers visit industries, industrialists visit schools, pupils get experience in factories, and teachers in training work as mathematicians in industry. We need in this country some serious investigations into how mathematics teachers might be brought--say, as a summer employment experience--into places where they can see mathematics being used and use it themselves.

<u>The Conditions of Mathematics Teaching</u>. Teacher, curriculum developer, researcher, mathematician--how can one reasonably expect the already overburdened and dispirited mathematics teacher to take on additional burdens and responsibilities, professionally challenging though they might be? The answer is that one cannot as long as the conditions of mathematics teaching remain as they are. That is what we mean by taking mathematics teaching seriously. If one does that, then one must, above all, work to change the conditions and the circumstances of mathematics teaching today.

> If society were to take seriously the job of teaching in the lower schools and, particularly, if teachers were to be encouraged to inquire into the substance of what they are teaching, or into the nature of students with whom they work, or into the learning process itself, it is apparent that a teaching load of more than twelve to fifteen hours per week could not be condoned....As long as we sanction teaching loads as burdensome as those which ordinarily prevail, our ingenuous talk of improving instruction will retain a faint touch of insincerity. No one, not even the most dedicated and brilliant, can effectively individualize instruction, systematically analyze his own teaching, diagnose learning difficulties, and maintain a vigorous pedagogical and substantive scholarship on a spare-time basis. (Schaefer, 1967, p. 61)

At least some assistance might be offered to the mathematics teacher by providing aides to handle the routine management tasks that have come to dominate much of the teacher's time. If the country had a national service obligation on the part of its youth, service in education might be an alternative to service in the military, the health services, or conservation. The national service obligation might also provide an opportunity to recruit young people into teaching as a career.

In the final analysis, people are attracted to and stay in teaching because of a vision they have of what teaching is and might be. Mathematics teaching today has become something other than what it was a generation ago, and it no longer looks inviting to enough talented people. All of us bear some responsibility for having made mathematics teaching a less attractive career than it used to be, and all of us need to work to change that situation.

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## DISCUSSION OF MATHEMATICS EDUCATION

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In "Taking Mathematics Teaching Seriously," Jeremy Kilpatrick and Jim Wilson have carefully reviewed some of the complex issues surrounding the shortage of mathematics teachers in this country and discussed several of the more popular proposals for the solution of this problem. In addition, they have given some special attention to the nature of the school mathematics curriculum and how this curriculum might be amended to meet the demands of today's technological society.

Given my current position as a department head, I would like to address my remarks chiefly to how we recruit more mathematics teachers and comment briefly on the more popular suggestions for alleviating the shortage.

Many believe that higher salaries might attract more mathematics and science teachers to the teaching profession immediately. The thought is a good one, to the extent that the mathematics or science graduate commands a much better starting salary if he or she decides to work in business or industry. But school systems cannot possibly compete with the private sector. Furthermore, differential pay schedules for certain segments of the teaching population will encounter considerable resistance from unions as well as from teachers who are not certified in shortage areas but will have been teaching for a much longer time than most who are.

Even assuming there are no major obstacles to this proposal for differential pay, however, it would appear preferable to focus on an even more important issue, and that is the issue of the quality of the teachers.

Quality is critical to any profession, and the very idea of lowering standards to fill shortages--or distributing additional resources and benefits to fill the need--is totally unacceptable. The problem lies in the faulty assumption that raising the salaries of mathematics and science teachers will automatically provide a cadre of talented teachers--teachers as committed to their students as the elementary teacher who has taught for 10 years and still makes a smaller salary than a beginning mathematics or science secondary teacher.

If differential pay is provided to mathematics or science teachers, school systems will have to ensure that the individuals who take those jobs are fully qualified and fully dedicated to their work. Schools will also have to be as exacting as industry when it comes to quality, shortage or no, if they are to maintain the necessary standards of teaching excellence.

The issues of quality also bear on the proposal to award forgiveable allowances to preservice mathematics and science teachers. School systems, Federal and State departments of education, and colleges of education need to be sure that they are attracting highly qualified men and women because they want to be teachers and not because of the financial benefits that will accrue.

Screening out individuals who are not well intentioned is very difficult, as we all know, but mediocrity, I believe, will be the consequence if we do not. We want and must insist on highly able and committed teachers, even at the risk of allowing the shortage to continue for a few more years.

It is my belief, too, that we should be wary of giving emergency certificates in large numbers. For the sake of the mathematics and science profession, the teaching profession, and also the students who are taught, the last thing we want is marginal teachers with no more than the fundamentals of mathematics and science preparing college-bound students for highly technical careers--not to mention a potentially rewarding career in teaching. Many underprepared teachers may fly back to the classroom merely to meet emergency certificate requirements, not so much to be excellent mathematics or science teachers but merely to improve their financial situations.

Another comment, it seems to me, is in order regarding some States which allow mathematics graduates who pass the National Teachers Examination (NTE) to be certified to teach mathematics--or science. Having substantial training in mathematics and being able to pass the NTE does not mean that an individual will be a good teacher. Some requirements should be established for these individuals to take courses in the fundamentals of teaching, some observation and participation in classrooms, and possibly even some student teaching. If our intent is to elevate a profession that is currently not taken seriously, we should demand no less of this category of teacher candidates.

Finally, we cannot treat the problem of mathematics and science teacher shortage in isolation. The entire teaching profession is affected by declining enrollments. I think Jeremy's analogy--I call it the Indiana Jones analogy, with the teacher in the bottom of the pit, and constantly being pointed at, told what to do, and still paid a marginal and meager salary--is on target. And if I were to take that one step further, I would talk about business and industry as being the "Raiders of the Lost Ark" who seem to be sweeping up all of the good mathematics and science teachers who are out there.

In 1969, 36 percent of college students were interested in teaching. In 1979 the figure had dropped to 10 percent. I think the figure now is somewhere between 3 to 5 percent. Between 1975 and 1977, the number of graduates qualified to teach fell from 243,000 to 190,000--a drop of almost 22 percent. And given we know that not all of the students who graduate in education elect to enter the teaching profession, it appears we will need to produce an even larger pool of qualified and certifiable teachers to make up the deficit.

Teacher education needs an image facelift which will have to be accomplished by teachers, the general public, and the press as well. Education will not be improved by constant criticisms of teaching quality and by waving low achievement scores on the front pages of local newspapers. When education gets the support and respect it needs and deserves, we are more likely to get a better system of education, and a teaching profession that more young people will seriously consider as a career.

As a final note, I would like to suggest as an element of the solution the creation of a Master of Arts in teaching for those mathematics or science students who go through the straight discipline program. It seems certain that this would serve to increase the pool of certifiable mathematics and science teachers. At the same time, I think that school systems will have to be able to offer such students something worth working very hard at for the additional year beyond their basic college coursework.

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I think Jeremy and Jim are right in their approach in the sense that the teacher shortage really has to be viewed as just one piece of a much larger concern for the quality of instruction in high school mathematics, and also a concern for the numbers of people and the types of people who pursue advanced mathematics. They cover an awful lot of ground, and that makes it easy for a discussant. My remarks do not have to be comprehensive. But I want to mention a few things that their paper triggered in my mind.

The first is one that Antoine touched on, too, and it may be a bit of a taboo in research on teaching. I think that estimating the magnitude of the teacher shortage on the one hand and thinking about the adequacy of proposed remedies on the other really requires that we have a fairly detailed understanding of the relationship between teacher knowledge of mathematics and the quality of mathematics instruction that they provide.

I say this is a taboo because I think if there were good studies on the matter, I would know them, or I would at least have heard about them, or at least the people that I talked to in preparation for coming to this conference would have known about them. But the area appears to be one that has not received a lot of empirical study. So I guess I call for that kind of study, but I do it with some reservations.

First of all, I think the studies better be well done. Otherwise you will guarantee the result: There will not be any relationship between teacher knowledge of mathematics and the quality of the mathematics instruction that they provide. I cannot believe that. That is an impossibility. So I am not really asking whether there is any relationship, but trying to see if through some empirical studies we can get a better handle on what the consequences are of dropping some of the certification requirements, for example.

Another thing I would like to mention is that most of the certification requirements are stated in terms of courses completed in higher education, and I am not sure we have a good understanding of what the influence of those courses is on the amount of mathematics knowledge that the students have. So I guess I am also calling for research on the adequacies of stating teacher certification standards in terms of coursework as opposed to some other way of demonstrating mathematics knowledge.

Also, it is my understanding that most of the certification is general. You are either certified or not certified to teach mathematics, and yet there are a lot of different kinds of mathematics that can be taught in high school. I wonder if there are places in the country that have experimented with the notion of certification for particular subareas of mathematics and what their experience would suggest about a more widespread practice of this type. It may even be that if there were certification for subareas of mathematics, that would ease some of the burden of a shortage, since, though I am not certain of it, I would think that training to become all things in mathematics would be more demanding than becoming competent in some specialty.

In addition to synthesizing and expanding research on relationships among teacher knowledge of mathematics, pedagogy, and the quality of mathematics instruction, the shortage of mathematics teachers might be better understood through comparative research across countries, occupations, and subject matter areas. One might ask, for example, if there are similar shortages of mathematics teachers in other industrialized countries, the United Kingdom for example. And if there are, are the apparent reasons for the shortages comparable to those in the United States? And what, if anything, is being attempted to remedy them? Also, are there industrialized countries which do not have a shortage? Perhaps Japan. And if there are such countries, how might their situation shed light on the causes and prospective solutions of the United States' problem.

Taking another tack, to what extent are other occupations requiring people with mathematics knowledge experiencing a shortage of trained personnel? To the extent that the degree of shortage varies across occupations needing similarly trained people, it may be possible to devise better remedies for the teacher shortage based on such information. What characteristics, for example, typify occupations with adequate supplies of mathematically trained people?

Looking at other subject matter areas, are there things about high school mathematics teaching that make it less attractive than teaching other subject matter areas? If so, what are they?

While there is a shortage of teachers for mathematics and a handful of other areas, there are in general more than enough teachers. What explains the profile of shortages and surpluses across teaching areas? For example, Jeremy and Jim cite the women's movement as a possible partial explanation of the mathematics teacher shortage and point out that the percent of prospective secondary mathematics teachers who are women has dropped in their university from 80 to 50 percent since 1970. But is this a differential effect on mathematics? And, if so, why?

According to a recent NSF report, 68 percent of high school mathematics teachers are male. While the number of people preparing to teach mathematics has dropped dramatically in the past decade, the decline in numbers has been less dramatic for women. In fact, nationally the percentage of women completing training has risen from 53 to 59 percent since 1972.

Other data from that same NSF report portray mathematics teaching in a relatively positive light. Mathematics is identified by the public as a subject most essential for all high school students. We have heard that before today. Mathematics teachers report fewer problems in support of their teaching than do teachers of either social studies or science. The percentage of high school teachers whose primary assignment is mathematics has actually risen from 11 to 18 percent since 1961. At least these limited data do not support the view that the teaching of mathematics is uniquely unattractive by comparison to other subjects.

Jeremy and Jim call for society and the educational community to take the teaching of mathematics seriously, but to what extent is the teaching of mathematics taken less seriously than the teaching of any other subject? A more careful look at this possibility seems in order.

I will skip comments on the notion of raising teachers' salaries except to say that I think that would be wonderful. If it can only be done for mathematics teachers, so be it, but if you could do it for all the teachers, that would be even better.

Under the rubric of curriculum reform, however, the shortage of high school mathematics teachers is only one piece of a larger problem. The quality of mathematics instruction using existing teachers, and the numbers and types of students who take advanced mathematics, are two other related pieces. Improving the quality of high school mathematics instruction and increasing the numbers of students taking mathematics, especially minorities and women, would benefit society generally and might ultimately solve the teacher shortage problem outright.

Jeremy and Jim focused on solutions at the high school level, giving considerable attention to curriculum reform and to teacher training and recruitment. Their discussion raises a host of interesting research questions.

For example, they advocate curriculum reform using the NCTM "Agenda for Action" in the 1980's, which emphasizes problemsolving and applications. I think this is an excellent document, and I highly recommend it. But it is a national agenda, and Jeremy and Jim state that, one, the school board should have ultimate responsibility for the curriculum; two, the arena for action is in the classroom; and three, teachers should have greater autonomy and be more involved in curriculum development.

These statements suggest a certain ambivalence about the determinants of school curriculum, an ambivalence which is undoubtedly based on past experience with mathematics reform. They lead me to ask what the factors are that influence high school mathematics teachers' content decisions? As a member of a team of researchers at the Institute for Research on Teaching at

Michigan State, I have been asking similar questions, but for elementary school teachers. For us, content decisions include decisions about how much time to spend on mathematics, what topics to teach, to what students, and to what standards of achievement.

In contrast to Jeremy and Jim's reports of teacher resistance we have been surprised to find that even relatively weak school policies concerning mathematics content can have a marked influence on what is taught. We consider such school policies as testing, curriculum objectives, grouping and promotion practices, textbook adoptions, and professional development.

In judging the strength of a policy, we draw on sociological theory. Thus, we consider the use of rewards and sanctions to give a policy power and attempts to make a policy authoritative through the use of norms, legal office, expertise, and support of charismatic leaders.

Across several studies, we find elementary school teachers reluctant to take the responsibility for making mathematics content decisions. Nevertheless, they are more often than not forced to make these decisions, either because of a lack of authoritative advice from the school hierarchy, or because of conflicting school policies that demand resolution at the classroom level. These findings have caused us to cast the elementary school teacher as a political broker in deciding the content of instruction, sensitive to the messages of content received but operating from their own conceptions of what is appropriate for their students.

Put another way, our research brings into question the claims of teacher autonomy made by the second-grade teacher quoted by Jeremy. Elementary school teachers do not seem to want total autonomy in deciding what mathematics to teach. They may, however, value autonomy more highly in deciding on the strategies they will use in delivering that content.

Similar research for high school mathematics would seem useful, although our results are clearly not directly transferable. For example, high school students have greater control over what subjects they will study. At the elementary level, these decisions are largely determined by the teacher. Also, high school teachers are for the most part subject matter specialists, while elementary school teachers are not. These and other factors may make high school teachers feel more strongly about controlling the curriculum.

While Jeremy and Jim's paper covers a wealth of issues in curriculum reform and teacher training, two areas that deserve further attention, at least at this conference, are the possible contributions of advances in cognitive science to improvement of mathematics instruction and the appropriate use of technology in the teaching of mathematics. Actually, that got a little bit more attention in the presentation than it did in the paper, which is appropriate.

But let me talk about cognitive science just for a second. Advances in cognitive science are providing new insights into the nature of student learning and thinking. For example, in both mathematics and science, it has been found that students hold misconceptions about basic concepts that stand in the way of their learning. Unfortunately, at least in the case of elementary school, the students' misconceptions are all too frequently shared by the teachers. When these conceptions are identified and directly challenged, however, student learning has been greatly enhanced.

I think there has been this schism between people who study student learning on the one hand and people who worry about research on teaching on the other. I do believe we have got to take a look at the advances in cognitive science and in thinking about training teachers in research on teaching.

Finally, one possibility that concerns me is that the problems of high school mathematics may have their origins in the elementary schools. During the first 8 years of school, all students study at least the mathematics that their teachers deem appropriate for them. From our research with elementary school teachers, we have discovered a great deal of variance in what students study within the same classroom and certainly from classroom to classroom.

For far too many students, however, too little of what is emphasized relates to mathematics as an important subject matter in its own right. Students may be learning to view mathematics as only a basic skill, with an emphasis on mathematics literacy and consumer mathematics. At the same time, we see little attempt on the part of teachers to challenge the social norm structures that operate to guide minorities and women away from mathematics.

During their elementary grades, student attitudes toward mathematics steadily decline. Still, mathematics is the single most popular subject for both 9- and 13-year-olds. And, in fact, minority students have a more positive attitude toward mathematics than do white students. However, it is open to question whether these attitudes extend beyond mere arithmetic to mathematics as a discipline.

By the end of eighth grade, students with their parents and their teachers make a decision as to whether they will go on to take advanced mathematics. This single decision will stay with them for probably the rest of their lives, with implications for the types of colleges they can attend, the college majors available to them, and ultimately the careers that they can pursue. Clearly it is in large part the student's achievements and attitudes from elementary school mathematics upon which these decisions are based.

Even more pronounced differences exist between college-bound majority and minority students, and in general I think we all agree that too few students take advanced mathematics.

Thus when looking at the high schools, one might also ask about mathematics in the elementary schools. And here the problems are if anything more difficult. The teachers are not mathematics specialists. As Jeremy and Jim hint in their paper, the shortage of qualified mathematics teachers in the elementary schools may be much more profound than the visible shortage in high schools.

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I just want to say that I really enjoyed studying two drafts of the paper by Jeremy and Jim, and I will go back and study the last one some more now. I am trying to arrive at an estimate of how much I agree with it and how much I disagree with it.

It reminds me of a conference some time ago, about 10 years ago, in which Piaget was one of the central figures, and a colleague of mine remarked to Piaget, rather obstreperously perhaps, "The structures that you are studying, Professor Piaget, really account for less than 10 percent of the field of human cognition."

And Piaget, with some umbrage, said, "How do you compute that percentage?"

But the next day Piaget said in his speech, "Of course, the structures which I am studying account for less than 10 percent of the field of human cognition"--with a straight face.

So I don't know how you compute that.

It reminds me also that I am feeling very reminiscent because I met Jim and Jeremy when they were working for SMSG and I was working for USCIM. And these two mathematics programs considered each other friendly rivals. I remember a meeting in which Ed Begle and Max Beaverman squared off in different corners of the room and went after each other.

George Poleo was at that meeting, and he got up afterward and said in an equally enigmatic way, "Max, I agree with 95 percent of what you're saying."

And I think that is about the right percentage, I agree with Jeremy and Jim about 95 percent. That is the last quantitative thing I am going to say.

I would like to tell you a few anecdotes which highlight the area where there might be some disagreement and perhaps even an area that hasn't really been touched on or explored yet which we might have some agreement about.

I do think that they are right that taking mathematics teaching seriously, or the failure to do that--the devaluation of mathematics teaching, and I would add the devaluation of mathematics thinking by students, the notion that mathematics has to be taught to students and cannot be reinvented by them themselves--that is one of the problems, one of the myths, if you like, that we need to reconsider.

Another myth I think we need to reconsider is that we can be happy with the curriculum that has been developed out of NSF projects, for example. I think a little in the way of mathematical criticism may be needed, but there may also need to be some social questions asked about whether society--school boards, teachers, parents, and so forth--wouldn't prefer for their own reasons and to exercise their own prerogatives to have a somewhat different curriculum than that.

Another myth I want to touch on a little bit is the role of teacher knowledge in teaching. To what extent is it essential that the teacher know the subject that is being studied by the students at the moment?

I would like to begin with a very brief account of something that Amy Grebe, one of our graduate students at Illinois, and I did. We did this work growing out of some videotapes which had been collected some years ago out of an NIE project. We reexamined the tapes, and we discovered an interesting phenomenon, that in kindergarten and in second grade, where we began the study, we could find in most classrooms--certainly the ones that we sampled, and later in other classrooms--that there were individual pupils who were operating quite independently of the teacher in thinking through things mathematically. They could be called mathematical mavericks. And the interesting and puzzling and disturbing thing about that is that all of them were white, middle-class male children. So we called them the pale male mathematics mavericks.

And we began to wonder: What happens? Why aren't there some female mathematics mavericks and some minority mathematics mavericks? And we began to look at what happens to children in primary grades who do some independent thinking about mathematics, for example, who figure out how to subtract starting on the left instead of the right the way the teacher tells them, or whatever. That is a classic.

We began to discover what happened to them, and the teachers began to explain to us that they were convinced that the most creative work in mathematics by students later on in elementary school came from those who had thoroughly mastered the algorithms in the beginning grades--how to add, subtract, and so forth--and that they knew it was expected by National social and local mores that minorities and girls in particular would have to be given some help and brought up to standard, to minimal competency. But if there is a boy who is outside of those targeted groups, and he seems to be doing all right, well, everybody knows he will be all right so we just let him go, and he may become an inventor or something.

So the white middle-class boys who took that approach seemed to get away without the requirement of minimal competency on mathematical skills defined as rigid procedures which had to be memorized and carried out.

That, you see, illustrates the point that teachers trying to carry out a mandate from above interpret it and apply it as they see it, looking up from the bottom of the pit, and they may in fact be undermining the intent for which these mandates for equality of educational opportunity were created.

It also arises because of their own view of mathematics as something that is arbitrary, that has to be memorized; it cannot be invented by the child himself or herself. And I would certainly second the various remarks that have been made about trying to help teachers understand that.

The next anecdote I would like to tell concerns a trip that my wife and I made to Japan. My wife speaks Japanese; I don't. But sitting together with her for 4 months in a Japanese elementary school, I was able to learn a lot--

both of us learned a lot. This was a very fortunate location that we found. It was a kind of inner-city school in Tokyo. The children's parents were either shopkeepers or temporary employees. I don't think any of them had these famous tenured positions with Sony or Toyota. Some 60 or 70 percent of the children had some form of welfare or government support of some kind.

There were 40 pupils per class. But the school climate was superb. The teachers and the students had regular breaks, 10-minute breaks, 20-minute breaks, five or six breaks during the day, when everybody is let out and each can go and do what he wants. Teachers go get a cup of tea or coffee, and the children run around and go see their friends, and the children with responsibilities for other children go check up on those, and so forth--kind of a lovely spirit, like summer camp, was the feeling we got.

What did they do in mathematics classes? The teachers gave these children challenging, difficult problems to work on. My wife, Elizabeth, and I invited some friends from the University of Tokyo to come and see this and interpret it for us, and they all said to the teacher, "Why don't you give them more help with these problems? Look, they struggled for a half-hour to try to figure how in the world you would use a protractor which only measures up to 180 degrees to measure an angle which is larger than 180 degrees, and you didn't tell them about the dynamic concept of an angle that gets bigger and bigger and bigger. Why didn't you just show it to them or use a Japanese fan?"

The teacher said, "That would make it too easy for them. We want something for them to struggle with because they need to learn to really try hard and persist, and that is more important than actually seeing that everybody gets the idea, because tomorrow we are going to do something different."

Indeed, they did change. They went very slowly and gave lots of time and encouragement and let children teach each other. Forty children in a class meant four to seven children in a group. And in a group they worked. These are heterogeneous groups. There's a bright child in every one.

So the children are teaching each other, and the teacher is a master of ceremonies. And the teacher may have been a mathematics major in college or may not--may have been a home economics major or something else. But the teacher never gave them very much in the way of mathematical instruction. Instead, the teachers taught the children how to behave, how to participate in a group discussion, how to share ideas and listen as well as speak, how not to dominate the discussion, how to take turns--all of these things. The teachers were excellent masters of ceremonies. In teaching these mathematics classes, they used very little of their knowledge, whatever knowledge they might have, of mathematics. They almost seemed, like the teacher I described, to hold it back and keep it away from the children and let the children struggle with it themselves. Testwise, these children were clearly way above levels of American schools we are familiar with.

I just want to tell you one more anecdote.

Coming back after this kind of experience, Elizabeth and I and some graduate students decided we should approach American teachers. And we found 12 teachers in Illinois who agreed that in primary school they had some problems in teaching mathematics and they would like to have some help. So we said, "All right, we will help you with your problems. And we have just had a lot of interesting ideas from Japan and other places, and we will try to bring these to you as resources which you can use or not use according to the way you see it."

Six of these teachers were in inner-city schools in Chicago. One of them, a third-grade teacher, had this experience--and I have time to give you only one teacher's experience. They were all different.

This teacher said, "One of my big problems is that I've been teaching third grade for 10 years in inner-city schools in Chicago, and I have never had a class of third graders who came up to grade level on the problemsolving part of the standardized test. I can get them up to grade level on computation and concepts, but not on problemsolving."

So we said, "Well, lets look at that."

So we looked at some previous tests, and we looked at the textbook, and we noticed that the textbook story problems are all at the ends of the sections that deal with computations. So they are a chance to apply--this is what Wilson and Kilpatrick have described--the computation skills you have learned.

But on the standardized tests you have a mixture. They are not all the same kinds of skills grouped together, so you cannot say, "Now this is a multiplication section, so I'm going to multiply all of these." In that case, you see, you wouldn't need to read the problem. You just find the numbers and multiply them. The children knew that very well, and that is what they were doing in this teacher's classroom.

As soon as she saw that, she said, "Oh, I see the problem. It never dawned on me before. What can I do about it?"

We said, "Let's make some new problems."

So we got problems from Japan and problems we sort of revised from standardized tests and other kinds of problems, and we just kept feeding this teacher challenging problems. When we gave her problems that required division and they hadn't studied division yet, she said, "We can't use this."

I said, "Go ahead; try it. See what they do with it."

And they did fine. They said they multiplied, but they got the right answer.

She learned one other important thing, that her planning usually called for doing about 8 or 10 or 12 story problems in a period, but if you let them discuss them, you'll only get one or two done because the children will have all kinds of ideas that you never dreamed of. And if you really allow that discussion and allow them to teach each other and criticize each other, then something will happen.

She said, "I see that's a good idea because that's what they need to be doing when they are taking the standardized tests. They need to be discussing it themselves silently and thinking. 'What is this about? Why should I multiply? Why should I subtract?'"

In short, it seems to me that sometimes, particularly in these areas of the primary school curriculum, what is needed is not so much subject-matter competence as some new insights about the way children can learn mathematics, can study mathematics themselves; and that this does not require a radical change in the curriculum because we can still use story problems, we can still use algorithms. Turning it around a little the other way, the Japanese children invented their own algorithms. Instead of memorizing an algorithm in order to apply it, they tackled story problems and then invented the algorithms to do them.

I would offer that, for whatever it is worth, a great deal can be accomplished by turning things around within the curriculum that exists.

## OPEN DISCUSSION

DR. SHULMAN: The kind of instruction that I hear Jack Easley calling for in the teaching of mathematics seems very different, at least at first blush, from the kind of direct instruction or active teaching that the literature of research on teaching seems to be calling for. And Tom Good has written many such studies arguing that direct instruction is the way mathematics ought to be taught, not the way you are suggesting. Do you two want to fight about that, or does someone want to comment on why they ought to or ought not to? I think this is a fundamental question about how mathematics ought to be taught and is potentially not a trivial disagreement.

DR. KILPATRICK: I think this is probably the key curriculum issue in mathematics education. The January issue of the Journal for Research in Mathematics Education carries an article by Bob Gayne in which he essentially argues that you must have automaticity of skills before you can proceed further in understanding mathematics.

That article has been received with considerable consternation by a number of mathematics educators, illustrating anew the kind of a split in perspectives that exists within the profession between those people who feel—and I think many classroom teachers are among this number—that you must have the automatic response before you can go further and those who do not. It is one of the reasons our curriculum looks the way it does.

But I think there is a large cadre of people who would be more sympathetic with the point of view expressed by Jack.

DR. SHULMAN: At the risk of putting you on the spot, Tom Good, is there a necessary contradiction between the work that you and Doug Grouws, among others, have been doing on the need for much more highly structured active teaching, as you call it, and the kind of teaching that Jack is proposing, and that Jeremy seems to maintain comes intuitively to many mathematics teachers?

DR. GOOD (Thomas Good, University of Missouri): I think the contradiction is more apparent than real when you get into the dynamics. For example, I would never argue that the role of the teacher would be to do the information processing or thinking for a student. I think that the processes that Jack was describing are the sorts of things you can get either through an inductive or a deductive approach, whether it's led by student discussion or through a teacher, depending upon the quality of those particular pieces.

That is, I think that the teachers, through careful modelling, through careful demonstrations, through challenging examples, through high standards, through high expectations, can create a sense of curiosity and interest that helps students to raise questions: What are the phenomena that I am examining? What question am I trying to address? How might I reexamine the pieces so that I can come up with another solution or another way of looking at it?

I think the search for patterns and solutions and the view of mathematics as discovery and a system of looking and thinking about phenomena can be taught, as well as be learned through discovery and other exercises.

I could go on and on. But in my view, the active teaching concept is not simply a statement of how mathematics ought to be taught. It reflects empirical inquiry describing how more and less effective teachers differ in their behavior.

I think a key element of that differentiation between teachers who are getting achievement gains and those who are not is the ability to focus upon meaningful conceptualization. We find, for example, that teachers who are getting achievement gains spend much more time on development, talking about ideas, doing mental computation, doing estimates, and doing verbal problemsolving, than teachers who do not get achievement gains.

Whether these things are occuring in student-led groups or because of a teacher in a classroom is basically irrelevant. I think that what is important in helping kids develop more significant, fuller conceptualization is placing qualitative demands on students and the way in which student progress is monitored and reacted to ultimately, particularly if misconceptions occur.

DR. EASLEY: I think I would agree with that 95 percent.

I think what might be left out is that we have a lot of teachers in our schools (who have a lot of students in their classes) who are nowhere near being prepared to do direct teaching, that is, to do what Tom has just described. But they are capable of doing it the way I described. And if that means that the more able students in the class are actually doing the teaching, so be it.

I could give you anecdotes which convince me that this approach needs to be looked at. It is something that has not been tried enough to show up in the studies of correlations that have been worked out.

DR. GOOD: A quick question. I really do not want to get into a polemical discussion because I am not really trying to advocate looking at teachers as being the only source of information in the classroom and the way to go, although I think they are an important source.

The question that I would raise is basically: when we have students teaching other students, is it not problematic in terms of the motivation, the seriousness, and the interest with which they will play those roles? I think to be able to articulate a positive learning environment will take an incredible type of teacher who has the skill to communicate beliefs, norms, and preferences that support this type of learning.

I would gather that in Japan there is a great deal of support from parents and society for the idea that mathematical learning is important, and it is expected the kids should participate fully in that.

Here, unfortunately, in many classrooms those antecedent conditions do not exist. I would argue that one thing we need to consider carefully is the lack of societal support and interest making it very much more problematic in our society to have that sort of active inquiry among students.

DR. EASLEY: I would say we learned a lot from the school in Japan. We observed and wrote up over a hundred mathematics lessons in that elementary school. We learned a lot about the things that teachers did to overcome these problems. They did exist, but they kept them to a very bare minimum by such clever devices as, for example, taking a general poll of the whole class when you have had reports from all the groups on what they have decided to do about this problem, and there is a lot of difference. Then, if you discover that the poll does not add up to the number of children present, you seek out the nonvoting children and find out why they did not vote. The teacher has to be very alert for the psychic dropouts, as Marshall McLuhan called them.

DR. AUSTIN: My name is Gwendolyn Austin and I'm with the Department of Education. I have two issues I would like to address because I notice on the program we have quite a few colleges of education, departments, and so forth, represented.

One of the concerns that I have is the lack of articulation in many institutions of higher education between the colleges and departments of education and the other disciplines. For example, the chemistry department, or the physics department. Private industry will actively go down to these departments and woo the graduates into their employment. What efforts have been made by your colleges of education to go down there and meet with those chemistry and physics majors and so forth to try to get them into the teaching profession, and perhaps following up on the second speaker's concept of a MAT or fifth-year program in those disciplines?

The other concern--one that Dr. Bell mentioned and Dr. Wilson alluded to--involves the use of microcomputers in the schools. Your State departments of education and your local education agencies have gotten on the bandwagon and are training teachers and students in computer literacy. How many of your colleges of teacher education, not your business schools, are providing future teachers with training to keep pace with this trend?

Those are the two issues that I am concerned about.

DR. WILSON: For the last 9 years, as part of the training of every secondary teacher, we have required at least one course in instructional computing. Some of them are now taking three courses, a three-course sequence in instructional computing, and some are taking a course in programming in the statistics department on top of that. So there is considerable work being done in the area.

Fifteen years ago when I went to the University of Georgia, and 14 years ago when I took over as department head, we had a very good dialogue going with the mathematics department. In fact, that has been a very productive interchange. We are not on their staff; they are not on our staff.

We teach 10 courses a year over there--"we" being the mathematics education faculty--and they do things in our department. They teach courses in our department occasionally, not as often as we teach in theirs. They are on our committees. We serve on some of their committees. As I have said, a very productive interchange. If there is anything to be said of our interaction with industry, it is that we have got too many of them coming in and hiring mathematics education graduates immediately.

We had, for example, a very good student defend her doctoral dissertation last week on a Thursday, and on Monday she started work for Southern Bell. It's happening at all levels and for all degrees. They are looking at us because we have, I think, strong mathematics backgrounds and strong interpersonal skills built into this.

Let me say also--in fact, I would make a flat statement--it is not the responsibility of mathematics teachers alone to deal with computer literacy, if at all. We want to deal with the use of the computers in teaching mathematics.

In the education of prospective secondary teachers, we expect them to deal with a faculty member through at least one course on the problems of mathematics curriculum. I'm not entirely happy with that, but it is a curriculum experience as a part of their training.

We also have a course on mathematics methods which is field-based. By the time they get out of that course, they know what a school classroom looks like. And the faculty members like Kilpatrick who teach that course also know what a school looks like, because they go out there and work in it.

These are components of what I think is important in a program.

DR. ALDRIDGE: As I have heard all the comments this afternoon, most of them have been directed toward the teacher or the student, and it seems to me that Joe Schwab may have been right about the corruption of education by psychology. Certainly we want to have good people, and the training of those people as individuals is very, very important. But the fact of the matter is schooling is a kind of a sociological phenomenon, and I think when Dr. Porter mentioned he was using some sociological variables, it buoyed me a little bit.

But I'm still wondering about the degree to which, in all of these questions that are being raised, we are considering the notion of the school as a unit that needs to be thought of as the setting. If curriculum is going to improve, if mathematics is going to improve, if those teachers are going to become involved, then certainly we need to be dealing with the school as the unit.

DR. KILPATRICK: Along with everything else, we tried to address that concern in our paper. We did discuss it. In particular, we were interested in some of the recent work on principals as instructional leaders and how principals might get curriculum development work going with other kinds of teacher activities.

But we are concerned with the school as a setting because obviously it's the conditions of teaching in that school that are going to impinge heavily upon the teacher's decision whether to stay in teaching or to leave.

DR. WILSON: I'll make it brief. It connects with the Secretary's remarks this morning about the certified master teacher, and this is analogous to the CPA. It's one that several of us have talked about in mathematics education. How do we provide a mechanism for removing or allowing people to exit from the profession who should be removed or allowed to leave? I think that goes along with any long-term consideration of improving the profession.

One other thing. When Betty talked this morning with dismay of the charts which showed the opportunities for studying science and mathematics are lower now than they have been in the past, her comment was--I think it was inadvertent--"...where will our scientists and engineers come from?"

And my thought was, "Where will our science and mathematics teachers come from?"

DR. SHULMAN: Let me conclude with a couple of comments. First of all, a reminder. Without knowing it, all of you were newsmakers today, and that newsmaking will become public on public television tonight at 7:30 on the MacNeil-Lehrer Report, which will be devoted to a discussion of the crisis in the shortage of mathematics and science teachers.

Ernest Boyer and Carl Sagan and Terrel Bell will be discussing those matters--unfortunately, not informed by all the wisdom that was exchanged here today, but we will watch that and think of how much better they could have done if they had been here to hear what we had to say.

Tomorrow we are going to make a transition from a concern with where we are going to find people to teach, and what do we know about the teaching of science and mathematics--the two major topics addressed today--to questions of the education of teachers for mathematics and science, and the role of teacher education programs in institutions in that activity.

In general I think much of our earlier discussion has been dominated by a metaphor, if you will, of teaching as telling, and that somehow the more you have to tell, the more you will be able to teach, and therefore the more kids will be able to learn.

In the outstanding work that both have done, though they may not agree on the particulars of teaching, I think that neither Tom Good nor Jack Easley would view teaching as lots of telling, and better teaching as more telling.

I think you have to conjure up what I might call the prototypical episode or encounter in a mathematics or science classroom. A teacher tells or demonstrates or explains something to a classroom full of kids. The telling goes on for a little while; the blackboard is used; perhaps some models are used. Maybe the kids play with some manipulatives. Then the teacher proceeds to ask a question which ought to be answerable by a kid who understands what he has just been told.

If the teacher is very lucky, she gets a right answer. If she is moderately lucky, she gets a wrong answer. And if she is as lucky as most of us are, she gets, "I don't know. I really don't know."

Now she is confronted with a dilemma. What do you do next? What doesn't the kid know? What isn't understood?

Drawing upon the six courses past calculus that she has taken, she says, "Sure you do. Try." And the kid is adamant and says, "I don't know."

Finally, in some desperation, she turns to another child who reliably does know. She responds and they move on.

I am afraid that a lot of what goes on in classrooms has that character. And what I want you to be thinking about is: What are the things that have to be in the heads of teachers, in addition to profound mathematical understanding, and in addition to general principles of classroom management and planning, that will make it possible for them to understand what it is that those children do not understand and have a set of options available that go beyond telling them the same thing over again, usually in a louder voice, the way we tend to try to get through to somebody who does not speak our language when we are in a foreign country.

This is a difficult question, but I think it may get to the heart of what we mean by improved education of teachers in mathematics and science. It may, if we keep that kind of image in our minds, help us go beyond recommendations that simply call for more mathematics and science for mathematics and science teachers.

A second thing I would ask you to think about--and it is related--has to do with a panel which is at the moment touring the country for the Association of American Medical Colleges. It is attempting to gather data as a basis for reformulating the medical curriculum in this country. Their preliminary report suggests that the problem with the medical curriculum is that medical students are taught too much of the wrong stuff and nothing of the stuff they need to practice medicine intelligently and humanely. The revolutionary character of this panel thus far is that they are not employing the typical curricular repair strategy, which is, "What do we have to add to the preparation curriculum to make it better?"

I am optimistic about their strategy, and so I recommend it for your thinking for tomorrow as well--not simply, "What do we have to add to the curriculum for teachers in order to make it better?", but, "How might we think through a reformation of that curriculum in light of these prototypical notions of what teaching is like?"

That would begin to solve some of the problems we have been addressing.

# SESSION V
# TEACHER EDUCATION: CURRENT CONDITIONS

## PREPARATION OF TEACHERS: MYTHS AND REALITIES

Anne Flowers, Dean, School of Education,
Georgia Southern College,
and
President-Elect, The American Association of Colleges
for Teacher Education

During the past several months, one had only to pick up a newspaper or journal to find some reference to the growing need for more and better science and mathematics instruction in our schools. The situation today is not unlike that we experienced some 25 years ago when we raced with the Soviet Union in attempts to explore space. The major difference is that we are facing a crisis that to a great extent results from our Nation's technological success.

Advances in science, medicine, and engineering have produced the phenomenon of technological obsolescence; knowledge is out-of-date before it can be incorporated into the curriculum of our Nation's schools. This phenomenon presents challenges for school systems for a scientific and mathematical literacy far different from the demands of previous years. In the wonderland in which we live, we find ourselves very much like Alice in her Wonderland running just to stay in the same place. And as we have for every other major crisis that has confronted our society, we are again turning to our educational system for a major initiative in seeking resolution to the problem.

The shortage of qualified mathematics and science teachers is identified by leaders in the education and business communities and by local, State, and Federal governing bodies as a critical problem and a national concern. The problem is even more serious than many realize. What confronts us is not merely an undersupply of technologically proficient and knowledgeable teachers, but a dwindling supply of qualified teachers that is compounded by the absence of incentives to attract young people to the teaching profession.

A solution to the teacher supply-demand imbalance for mathematics and science will not be found without facing the broader problems challenging the schools, the profession, and teacher education. Relying on an issue-specific panacea, ignoring the complexities and interrelationships of education in this country, will only serve to mask serious underlying problems that cry for resolution. Without a doubt, it is time to dispel the myths and to identify and discuss the realities of our educational system. Then, and only then, can we move to enact appropriate reforms.

The dilemma we face has developed over a period of years. It has been nourished by apathy, disinterest, and neglect by Government, schools, colleges and universities, the military, and our citizenry. The price we are paying is the failure to maintain general scientific and mathematical literacy among the population at large. It is time to face the issue squarely, to rethink our priorities, and to reconceptualize our practices. It is time to change and for change. And I, for one, applaud the National Institute of Education for providing a forum for our deliberations.

## THE MYTHS AND THE REALITIES

The theme of this conference is "Teacher Shortage in Science and Mathematics: Myths, Realities, and Research." In addressing that theme, I would like to frame my remarks around eight myths commonly associated with teacher education, while realizing that in each myth, there is some reality and that in each reality, there is some myth.

### Myth: The Schools are Failing

Reality: No other Nation serves so large or varied a student population as does this country, with more young people attending school, graduating from high school, and matriculating to postsecondary institutions.

Lawrence Cremin (Note 1) calls the following figures "extraordinary statistics:" 96 percent of our 16-year-olds, 90 percent of our 17-year-olds (the year after compulsory school attendance ends), and 83 percent of our 18-year-olds are in school. Eighty percent of our youth graduate from high school, and 65 to 70 percent go on to some sort of postsecondary education. In Cremin's view, although these remarkable numbers are taxing our methods, approaches, goals, financial resources, and "confidence in our ability to conduct a universal school system," we are providing a remarkably successful education program.

Parallel to these "extraordinary" numbers, the schools have provided access for all young people in the society regardless of race, sex, or social class. During the 1970's the proportion of high school graduates among the black 18- to 24-year-old population increased from 60 to 70 percent, while for the first time, total enrollment of females in higher education grew faster than that of males (Dearman and Pliski, 1982, p. 130; 133). Women in increasing numbers attended schools of law, business, dentistry, and medicine. For the first time, last fall's enrollment of women outnumbered men in the Michigan State University Medical School.

During the 1970's, the schools also helped in the assimilation of 12 million immigrants--the largest wave of immigrants of any decade in American history (Hodgkinson, 1982). The schools played a key role in assimilating these people into American society at the same time that the schools were mainstreaming increasing numbers of handicapped children into regular classrooms, with a majority of all handicapped children spending fewer than 10 hours per week in special education programs. The years between 1970 and 1980 were also noteworthy because of the success of the schools in providing "Lau remedies" for bilingual children, ending sex-role stereotyping in materials and textbooks, increasing the attention given to career and vocational education, dealing with the environmental education movement, and teaching the skills of active citizenship.

Not only are the schools providing education to more and more of the population, but they are providing a quality of education that has remained remarkably constant across the past 10 years, despite the infusion of new populations and distractions. With the exception of the Scholastic Aptitude Test (SAT), measurable qualities of students on other examinations have shown remarkable consistency or slight gains. Hodgkinson points to the fact that there have been no significant declines in the American College Testing Program, the Preliminary Scholastic Aptitude Test, or the Graduate Record Examination results during that period of time. Indeed, since 1980, reading scores have increased significantly in several major metropolitan areas, and the president of the College Board recently announced that "the long-term decline in SAT scores has been halted by 1982 seniors" (Howard, 1983, p. 19).

The myth of failing schools just does not hold up under the scrutiny of examination. The great challenge of conveying new scientific, technological, and humanistic literacy during the coming decade can be met by the schools. And if we enact appropriate school policies, the schools will again succeed.

Myth: There Are Already Too Many Teachers

Reality: Throughout the 1970's, there was a substantial oversupply of new teachers. However, college students have responded to the teacher surplus by enrolling in other fields of study.

The annual supply of newly qualified teacher graduates decreased from 314,000 in 1971 to 159,000 in 1980, creating a situation of shortages in certain geographic regions and curricular areas (Frankel, 1982, pp. 71-92). The most dramatic undersupply has been of mathematics and science teachers. Recently, significant attention has been given to reductions in the number of potential science and mathematics teachers being prepared and their attrition from careers in education to business and industry. Between 1970 and 1980, there was a 77 percent decline nationwide in the number of secondary mathematics teachers prepared and a 65 percent decline in the number of secondary science teachers being trained (Hurd, Note 2). In my own State of Georgia, for example, only 70 prospective mathematics teachers were graduated from colleges and universities during the 1981-82 school year. Of these, only 42 took classroom positions, with a dropout rate for the first year of 34 percent, or 14 new teachers. We anticipate that this number will continue to decline at a rate of 10 percent per annum.

A recent study of experienced mathematics and science teachers indicated that nearly 30 percent were leaving the classroom for other employment or intended to do so in the near future (Renirie, Note 3). What is most disturbing, however, is the National Science Teacher Association's finding that younger teachers are leaving the schools at a greater rate than older teachers (Walton, 1982).

Additionally, collective bargaining agreements are taking their toll in that they often result in the dismissal of newly hired mathematics and science teachers under "last-hired, first-fired" provisions. With the average age of science teachers being 41 (Klein, Note 4)--some 8 years older than the mean of all employed teachers--and young teachers leaving the profession at an unprecedented rate, we are faced with an older faculty and insufficient new personnel entering for replacement. We are running out of time to prepare replacements as these older teachers move closer to retirement.

Dramatic reductions in numbers of students being prepared as mathematics and science teachers and devastating losses of young teachers to business and industry are only one dimension of the problem that we face. Shortages and potential shortages of teachers in other disciplines are even more critical because State and Federal policymakers, in their rush to remedy perceived scientific and technological inadequacies, are ignoring them.

A study by the Association of School, College and University Staffing revealed that significant teacher shortages exist not only in mathematics, chemistry, physics, earth science, and data processing, but also in industrial arts, agriculture, learning disabilities, bilingual education, special education (emotionally disturbed), speech pathology/audiology, and special education for the multiply-handicapped ("Teacher Supply/Demand," 1982). Obviously, these current shortages must be faced, but recognition must also be given to other approaching teacher shortages. In Florida, for example, foreign languages, language arts, elementary education, and special children's education are the next areas in which personnel vacancies are anticipated in a deepening shortage of qualified teachers for all areas (Teachers for Florida Schools, 1982).

The shortage of qualified teachers is real, and it is becoming more severe. As noted earlier, enrollments in college and university education programs have fallen from 317,254 in 1972 to 159,485 in 1980, a loss of almost 50 percent (Graybeal, 1981). Over one-half of all States reported unfilled teaching positions between 1980 and 1982 (McGuire, Note 5).

In predicting greater teacher shortages for the late 1980's, the National Education Association reports that fewer of those prepared to teach will actually choose to do so. (Now, some 75 percent of the education graduates actually enter teaching.) In addition, many of those presently teaching will find employment outside of the field, particularly when the general oversupply of college graduates begins to drop in the late 1980's and we experience a labor shortage/job surplus condition ("Teacher Demand Has Declined," 1982). The National Center for Education Statistics supports this contention with one set of projections that suggests that, by 1985, the supply of new teachers will fall short of the demand by almost 15 percent, a figure that may likely continue to rise into the 1990's (Frankel, 1982, pp. 71-92).

A number of factors have contributed to the decline in enrollments in education. One is the teacher surplus of the early 1970's and continuing public perceptions of an oversupply, coupled with the widespread belief that teacher education graduates are employed only in schools. These perceptions contribute to negative attitudes of high school students in considering teaching as a career. In 1981, only 3.5 percent of entering college students expected to become elementary teachers, and only 2 percent expected to teach on the secondary level (Guthrie and Zusman, 1982).

Another factor contributing to declining enrollments in teacher education programs is demographics. On the basis of the current high school population, colleges and universities must prepare for a decline in the number of postsecondary students, a situation that is expected to continue until the late 1990's when enrollments will "once again surge" (Breneman, 1982). As a result, schools, colleges, and departments of education must compete with other university programs for a limited number of students. Were the present decline in teacher education enrollments paralleled by a decline in the birthrate, there might be fewer concerns for the future. The reality, however, is that the birthrate began to rise in 1978 due to childbearing among post-World War II "baby boom" children. The consequence is an upturn in elementary enrollments beginning this year and, therefore, increases in secondary school enrollments beginning in 1989 (Guthrie and Zusman, 1982).

Recent declines in the number of students electing careers as mathematics or science teachers, and in some cases in other disciplines, have forced universities to close smaller teacher preparation programs. Only 600 of our 1,350 teacher preparation institutions currently graduate mathematics teachers (Mathematics Teacher Shortage, 1982, Note 6). Even when a university recognizes the need for a teacher education program, it cannot implement the program without an initially sufficient number of students and a commitment of external funds. Consequently, limited numbers of students who choose a college or university without consideration of its teacher education offerings will find that there is no program for them.

One segment of the teaching force that is increasingly disturbed by these enrollment trends is Black educators. According to Equal Education Opportunity Commission data reported by Witty (1982), from 1975 to 1978 the percentage of Blacks in school positions (teaching and nonteaching) fell from 12.9 to 12.3 percent. In addition to overall enrollent reductions, Witty identifies a series of contributing factors: job losses resulting from desegregation efforts, expanded minority employment opportunities, decline in the quality of elementary and secondary school education for Blacks, and testing and screening practices for entry into education programs and for initial certification.

Concerns about the quality of teaching as a profession, institutional retrenchment, and expanding professional opportunities for women and minorities have resulted in a significant reduction in the pool of potential teacher candidates. Rigorous recruitment strategies must be implemented to bring these persons back into the profession.

<u>Myth: Certification Waivers Will Bring Good Teachers Into The Classroom</u>

<u>Reality</u>: The placement of unprepared individuals in classrooms through emergency certification is all too commonplace. In Pennsylvania last year, some 1,300 waivers were awarded, while in Ohio the number was at least four times greater.

Awarding emergency certificates is bad education policy and an inappropriate response to the shortage problem. State certification requirements serve the essential purpose of establishing criteria for determining minimum standards of preparation for elementary and secondary school teachers. The requirements are designed to protect children from unprepared and unqualified teachers. While granting that there are teachers in the classroom who have met the minimum requirements for certification and who are not performing satisfactorily, the danger of increasing these numbers by waiving minimum standards is frightening. Can we afford to take that chance? Indeed, can we have both a commitment to educational excellence and encourage the placement of untrained teachers in our schools?

According to a survey conducted last year by the National Science Teachers Association, 50 percent of newly employed secondary mathematics and science teachers were considered unqualified by their principals (Walton, 1982). Such a statistic is unacceptable. Although bright, caring arts and science graduates are available, we are compelled to ask if they are qualified to teach. Our first question must be, have they chosen to teach because they did not meet the requirements for employment in their own fields of preparation? Then we must further inquire: Do they know about sequencing of content or curriculum development? Do they know about test construction or the interpretation of standardized tests? Do they know about learning theory or understand how to manage a class of 30 unique individuals who come from diverse backgrounds or who do not want to learn? Do they know about diagnosing various handicapping conditions or developing appropriate educational programs? Do they have a repertoire of teaching methods, instructional strategies, and resources to use in various situations and with different children?

If certification standards need modification because they are inappropriate or unworkable, it is the responsibility of State government, the profession, and teacher preparation institutions to review these standards and develop the necessary revisions. Abandoning a system designed to assure minimum standards in order to accommodate a quick solution not only does not solve the problem, but also weakens the entire educational system.

Myth: If We Pay Enough, We Will Get The Teachers

Reality: Compensation for teaching is much lower than it should be, but simply raising salaries is no guarantee that schools can attract an adequate number of qualified candidates. Although teacher candidates continue to be attracted to teaching for a variety of intrinsic reasons, the significant decrease in the buying power of teachers' salaries during the 1970's made it imperative to address the "conditions of practice." The problem is that simple adjustment in beginning teachers' salaries, particularly for teachers of science and mathematics, will not make those salaries competitive with other sectors.

According to the National Education Association, the 1980-81 average starting salary for public secondary school teachers was $11,758. In comparison, a graduate of a 4-year college degree program in engineering can earn $22,368; in accounting, $16,980; in chemistry, $19,536; and in computer science, $20,364 (Guthrie and Zusman, 1982). Although one can easily make a case for teachers' drawing similar salaries, school districts simply cannot outbid business and industry for personnel. Matching the minimum salary offered by industry would necessitate doubling most school districts' personnel budgets. With the current administration proposing a 30 percent reduction in Federal support for education and many States reporting additional cuts in State aid, it is unrealistic to expect that major adjustments can be implemented, particularly in economically distressed States and regions.

Since school districts cannot outbid business and industry for teachers on the basis of salaries, it is proposed that they join forces. Given the fact that the attrition of practicing teachers is a reality and fewer and fewer teachers are making teaching a long-term career, we are suggesting a series of strategies to effect needed reforms.

Nearly 60 percent of those initially employed as teachers eventually take employment in other occupations. Many view this fact as a problem. With some imagination this situation could be turned into a genuine resource for both school and prospective employers. American business and industry, and education policymake s in particular, must be made aware of the importance of well-qualified teachers and of the consequences to our communities, States, and Nation of unqualified teachers.

Partnerships of schools and businesses need to be formed. Business and industry could continue their practice of hiring recent graduates of mathematics and science teacher education programs, but they could then place them in public schools during the first 3 to 5 years of their employment with their company or on a part-time basis during a similar period. During summers the companies could provide employment and/or support for further education. Various tax incentive packages can be considered to put this option, developed by my colleague John Sandberg of Western Michigan University, into place.

If economic realities dictate that teachers' salaries may not be able to compete with those offered by industry, a variation of the first option is to explore ways to provide teachers with meaningful summer employment opportunities. Legislation introduced last year in the House of Representatives and the Senate suggested a tax credit for those businesses providing mathematics and science teachers with summer jobs. This concept could be broadened to encompass teachers in all disciplines; and rather than placement in just business or industry settings, colleges and universities might be encouraged to hire teachers for summer assignments. Museums, think-tanks, libraries, and State and local governments could, with modest incentives, provide teachers with meaningful summer jobs. These collaborative efforts between business and education would not only offer teachers work during summer vacations, they would also expand industry's personnel pool and increase teachers' contact with the practical application of skills and knowledge.

Further, we must address the professional growth of classroom teachers through appropriate inservice activities that will contribute to both their subject matter knowledge and professional growth. We must develop and deliver inservice programs that address both academic and professional needs. Incentives for States to conduct programs with school districts and institutions of higher education are appropriate. The National Science

Foundation's model of summer institutes for elementary and secondary school teachers is a viable option. These institutes could also provide retraining for those former teacher graduates who are currently not employed as teachers by enabling them with additional preparation to move into high school positions in mathematics and science.

I urge that we consider ways of developing a support system for new teachers as they move from the college or university into a classroom setting. Cooperative programs between institutions of higher education and school districts should be initiated to provide entry-year mentoring and support programs for first-year teachers. Teachers in all subject areas should be given reduced teaching loads to permit their effective development as beginning teachers.

The environment for instruction should be made conducive to learning and teaching. We should provide our teachers and schools with adequate laboratory facilities and teaching materials. Although 95 percent of academic time is spent with instructional materials, less than one cent per dollar is spent for textbooks and similar materials (Science and Mathematics in the Schools, Note 7). Additionally, teachers need to be given some reprieve from the myriad of noninstructional duties that deplete their energy and reduce their actual teaching time. Clerical and laboratory assistance should be made available to take over such duties and free teachers to do the job for which they were employed.

Many classroom conditions contribute to teacher dissatisfaction and "burnout," according to Dean D. Corrigan, past president of the American Association of Colleges for Teacher Education (AACTE) and Dean of the College of Education at Texas A&M University:

> We can mandate competency tests, evaluate and screen candidates and prepare our teachers with the latest knowledge and skill, but if we then place them in work situations where they cannot use this knowledge and skill we will merely produce more candidates for the teacher drop-out list....The critical point is that conditions for professional practice do not exist widely, either financially or psychologically for the teacher today. Our efforts as professional "teachers of teachers" will fail unless we can create more favorable conditions in which our graduates can practice their newly acquired knowledge and skill (Corrigan, Note 8).

The conditions of practice significantly affect our ability to recruit and retain sufficient numbers of qualified teachers. We have high expectations of our teachers: superb academic preparation from the schools of arts and sciences, strong professional preparation and sufficient supervised experiences in the classroom, and expertise in the latest in science and technology. Yet, we supply out-of-date equipment and materials and pay education professionals far less than others with similar backgrounds and preparation. Why are we surprised when these people choose not to remain in the classroom?

Myth: Teaching Is Just a Matter of Common Sense

Reality: Teaching is a highly complex process requiring persons of exceptional knowledge and skill. The myth seems based on the conventional idea that teaching is a simple didactic process of conveying knowledge to learners and that any reasonably intelligent person with proficiency or skill in a selected discipline or subject can be effective in accomplishing this objective. Unfortunately, the belief was given added credence by selected researchers in the early 1970's. Their results were interpreted as indicating that teachers made little if any difference in student learning. Today that attitude results in various study groups and commissions proposing that graduates with baccalaureate degrees in arts and sciences be sent into classrooms to learn "on the job" without any professional preparation.

The research of the past decade on teaching performance related to student learning has shown that different teachers can generate significant differences in young children's learning of the basic skills--particularly in reading and mathematics. Teacher educators have been examining these basic differences in the research of Berliner, MacDonald, Stallings, Gage, Brophy, Good, Biddle, and others and attempting to fashion appropriate professional preparation programs. Smith and his colleagues in Florida are looking at the roles and functions of teacher as teacher, teacher as person, and teacher as professional. Each of these roles is then divided into other content areas. For example, the role of teacher as teacher is divided into the following categories: (1) diagnosis; (2) instructional planning; (3) instructional management; (4) observation; and (5) interpersonal relations. The Florida model assumes that candidates for teaching need to know the undergirding research base and be able to practice effectively the identified knowledge and behaviors (Handbook of the Florida Performance Measurement System, 1982).

Teaching is a complex process, and beginning teachers must have far more than just common sense when they begin to practice the art and science of teaching. While teachers need to be well educated in liberal and general studies, AACTE's forthcoming Profile of Excellence for a Beginning Teacher also argues that all beginning teachers must demonstrate specific forms of knowledge: (1) knowledge of learners--their individual differences and special learning needs and styles of learning; (2) knowledge of teaching methods, including differentiated instruction and classroom management; (3) knowledge of resources appropriate for specific learning levels and the use of a wide variety of teaching tools, including computer-aided instruction; (4) knowledge of evaluation, including the validation and interpretation of tests; (5) knowledge of education setting, the nature of the school as an institution, and the ability to work with parents; and (6) knowledge of the profession of teaching and the ethics that guide it.

Professionally prepared persons should be able to sequence content and develop appropriate curriculums, construct tests and interpret standardized scores, effectively manage a class of 30 unique individuals, diagnose various handicapping conditions and develop appropriate individualized programs, understand the laws that shape the rights of both learner and teacher, and possess a repertoire of instructional strategies to use in various situations and with different children. These tasks are only some of those required in the most complex of human occupations--that of teaching.

Myth: Teacher Education Students Are Not Very Smart

Reality: Substantial publicity has been given to studies of high school students indicating that those who are considering teaching careers have lower test scores and grade point averages than college bound students as a group. From this publicity it has been generalized that all students enrolled in college or university teacher education programs, or, furthermore, those who complete the programs, are substantially less academically able than students in other disciplines.

In 1982 students admitted into teacher education programs as college juniors scored an average of 866 on SAT's taken 2 years previously as high school seniors (Accreditation Data Bank, Note 9). Although lower than the mean SAT scores for all students, this score is higher than SAT's reported in 1979 for education-bound students. On the ACT, also administered to high school seniors and used for college admission, 1982 college juniors entering teacher education programs scored about the mean high school score. Taken together, these data suggest that students planning careers in education are neither academically superior nor inferior to other students.

Admission to teacher education programs is not made casually. Students must meet university requirements and complete a program of general studies with an acceptable grade-point average prior to beginning their professional preparation. Many universities require that potential teacher education students, in addition to having the academic credentials, pass entry or preprofessional tests prior to admission to the program (Sandefur, Note 10). A recent study conducted by AACTE (Note 9) revealed that junior students admitted for the 1981-82 school year into a teacher education program in a sample of 200 institutions, carried a 2.8 grade point average in general education courses. This survey also indicated that the average GPA of June 1982 education graduates was 3.0, higher than minimum institutional requirements but consistent with GPA's of students entering the program. Together, grade point averages and ACT scores suggest that the abilities of education students entering and completing a teacher preparation program are equal to those of students in many other fields of study.

This information does not ignore the fact that the pool of talented students who express interest in teaching as a career has diminished. Schlechty and Vance (Note 11) have reported that the current teaching pool is not only smaller, but is also characterized by an absence of the large number of very academically able, particularly women and Blacks. The issue is not, as Schlechty and Vance correctly point out, lower standards for entry into teacher education programs; rather, it is a recruitment and retention problem. Average students are electing teaching as a career because we grant the profession barely average status and below-average salaries. It is essential that we begin to search out good people and provide incentives for them to enter and remain in the profession.

Myth: Teacher Education Students Spend All Their Time in Professional Education Courses

Reality: Candidates for secondary school positions in mathematics and science take a highly rigorous college program--much of it in science or mathematics. Typically, a teacher preparation program is made up of four components: a solid foundation in general education in arts and sciences including basic skills; advanced or specialized study in one or more academic subjects; professional education courses in methods, theories of learning, and foundational studies; and a student teaching experience.

Preliminary data from an AACTE survey of some 100 schools of education reveal a wide range of semester hour requirements for secondary teacher education programs in mathematics and science (Study of Science and Mathematics Education Programs, Note 12). For teacher candidates, general education requirements range from 37 to 61 semester hours of a typical 120-130 semester hour program. Students specializing in mathematics education are required to take an average of 33 additional semester hours of specialized mathematics courses. Those in science education must take an average of 41 additional hours in specialized science courses.

In this same sample, professional education courses averaged only 25 semester hours of the total mathematics or science education candidate's coursework, with student teaching consuming almost one half of these hours. The range of professional coursework is consistently smaller than for general education and academic specialization categories (Note 12). This survey reported that, while all candidates are enrolled in a teaching experience, schools of education are requiring significant semester hours of additional school-based experiences. The reality is that pedagogical studies consume only a minor portion of the secondary mathematics and science education candidate's undergraduate preparation.

To illustrate this further, the teacher education programs of three different institutions are depicted in Exhibits 1, 2, and 3. The institutions involved are typical of those preparing teachers: one is a large land grant institution, another a major producer of teachers and former normal school, and the third is a small liberal arts college with a quality teacher education program.

While one purpose in depicting programs of study for mathematics and science education candidates is to refute the image of students spending inordinate periods of time in professional programs, another purpose is to point up a problem in the preparation received; namely, in a major in mathematics or science, there is little in the college curriculum that can be directly applied to the teaching of high school algebra or biology. Indeed, it should be recognized that the very advanced subject matter training given these students *may* inadvertently serve as a disincentive for them to enter secondary classrooms.

Exhibit 1

## Mathematics Education Major's Requirements
(Large Land Grant Institution)

### General Studies

| | | |
|---|---|---|
| I. | Math-Philosophy | 6 hrs. |
| II. | Physical Sciences (required) | 6 hrs. |
| III. | Biological Sciences (required) | 6 hrs. |
| IV. | Foreign Languages | 6 hrs. |
| V. | Humanities; Literature and the Arts | 6 hrs. |
| VI. | History (required) | 6 hrs. |
| VII. | Social Sciences (required) | 6 hrs. |
| VIII. | Behavioral Sciences | 6 hrs. |

### Special Preprofessional Studies
(20 semester hours)

| | | |
|---|---|---|
| Freshman English | | 6 hrs. |
| Communications and Humanities | | 3 hrs. |
| | From English, Communications, Humanities, Journalism, Philosophy, Religion, and Speech. Three hours must be literature. | |
| SP 181 | Basic Public Speaking | |
| or | | |
| COM 101 | Introduction to Communications | 3 hrs. |
| BIO 110 | Introduction to Human Biology and Health | |
| or | | |
| HPR 145 | Concepts in Health and Fitness | |
| or | | |
| NFS 101 | Food and Nutrition for Man | 3 hrs. |
| PSY 100 | Introduction to Psychology | 4 hrs. |

### Professional Education
(27 semester hours)

| | | |
|---|---|---|
| EDP 202 | Human Development and Learning | 3 hrs. |
| EDU 203 | Teaching Exceptional Learner in Regular Classroom | 3 hrs. |
| EDF 301 | Education in American Culture | 3 hrs. |
| EDC 344 | Principles and Techniques of Teaching in the Secondary School | 3 hrs. |
| EDC 521 | Materials and Methods in Teaching Mathematics in Secondary School | 13 hrs. |
| EDC 356 | Student Teaching in Mathematics | 12 hrs. |

### Advanced or Specialized Study in Mathematics

Students majoring in secondary mathematics will select <u>one</u> of the following three programs:

<u>Plan One</u>: Mathematics major of 30 hours and any minor listed.

Exhibit 1 (continued)

Plan Two: Mathematics major of 30 hours and two fields of 12 hours each chosen from the following Support Areas:

| | |
|---|---|
| Astronomy | Economics |
| *Biological Science | Engineering Drawing |
| Chemistry | Physics |
| Computer Science | Statistics |
| Earth Science | |

Plan Three: Mathematics major of 30 hours and any combination of 24 hours from areas related to mathematics such as (courses in other areas may be selected with advisor's approval):

| | |
|---|---|
| Astronomy | Economics |
| *Biological Science | Engineering Drawing |
| Chemistry | Physics |
| Computer Science | Statistics |
| Earth Science | |

Major in Mathematics (30 hours) (MA 122 may not be part of 30-hours major)

Required:

| | | |
|---|---|---|
| MA 113 | Calculus I | |
| or | | |
| MA 115 | Elementary Analysis I (Honors Math) | 4 hrs. |
| or | | |
| MA 117 | Differential Calculus | |
| MA 114 | Calculus II | |
| or | | |
| MA 116 | Elementary Analysis II | 4 hrs. |
| or | | |
| MA 118 | Integral Calculus | |
| MA 213 | Calculus III | |
| or | | |
| MA 215 | Elementary Analysis III | 4 hrs. |
| or | | |
| MA 217 | Calculus of Several Variables | |
| MA 341 | Topics in Geometry | 3 hrs. |

*Biology 110 may not be used as one of the courses in the Support Area.

Exhibit 1 (continued)

Strongly Recommended:

| | | |
|---|---|---|
| MA 261 | Introduction to Number Theory . . . . . . . . . . | 3 hrs. |
| MA 262 | Linear Algebra . . . . . . . . . . . . . . . . . . | 3 hrs. |
| MA 361 | Elementary Modern Algebra I . . . . . . . . . . . | 3 hrs. |
| MA 371 | Elementary Set Theory and Numbers System . . . . . . . . . . . . . . . . . . | 3 hrs. |

Electives: (to be selected with the aid of an advisor)

| | | |
|---|---|---|
| MA 214 or MA 218 | Calculus IV / Calculus for Mathematics Majors IV | 3 hrs. |
| MA 351 | Elementary Topology I . . . . . . . . . . . . . . | 3 hrs. |
| MA 352 | Elementary Topology II . . . . . . . . . . . . . | 3 hrs. |
| MA 362 | Elementary Modern Algebra II . . . . . . . . . . | 3 hrs. |
| MA 410G | Mathematics for Economics . . . . . . . . . . . . | 3 hrs. |
| MA 411G | Models in Mathematical Biology . . . . . . . . . | 3 hrs. |
| MA 415G | Graph Theory . . . . . . . . . . . . . . . . . . | 3 hrs. |
| MA 441G | Geometry I . . . . . . . . . . . . . . . . . . . | 3 hrs. |
| MA 442G | Geometry II . . . . . . . . . . . . . . . . . . . | 3 hrs. |
| MA 471G | Advanced Calculus I . . . . . . . . . . . . . . . | 3 hrs. |
| MA 472G | Advanced Calculus II . . . . . . . . . . . . . . | 3 hrs. |
| MA 481G | Differential Equations I . . . . . . . . . . . . | 3 hrs. |
| MA 501 | Seminar in Selected Topics . . . . . . . . . . . | 3 hrs. |

Exhibit 2

Science Education Major's Requirements
(Large State College)

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In addition to general studies and requirements for the Teacher Education Program, science teacher candidates must complete the following program:

Science Teaching Major (minimum of 51 semester hours)

This major may be added to the Secondary Instructional License; its coverage is grades 9-12. Students who elect to complete a Secondary Science License are required to take three components as part of the Science Major. These components are general requirements, one primary area, and one supporting area. The primary and supporting areas include the following: biology, chemistry, earth space science, general science, mathematics, physical science, and physics.

Prerequisite courses for the Science Major may be taken as part of this General Education category of electives. In addition to these requirements, students must complete a two-hour methods course in the primary area and a two-hour methods course in the supporting area.

General Requirements (12 semester hours)

Any combination of the courses listed below will fulfill this requirement with the stipulation that each course is selected from a different discipline. (Courses used to satisfy this requirement may not also be used to satisfy requirements in the primary or supporting areas.) Chemistry 105--3 hrs., 105L--1 hr. or 107--4 hrs.; Geography and Geology 111--3 hrs. (111L--1 hr. recommended) or 113--3 hrs. (113L--1 hr. recommended); Life Sciences 101--3 hrs.; 101L--1 hr.; Physics 105--4 hrs. or 205--5 hrs.

Students must complete two self-paced instructional modules concerned with drugs and nutrition or an approved substitute.

Primary and Supporting Areas

Students who elect a Science Major with primary or supporting areas in biology (life sciences), chemistry, earth space science (geography and geology), mathematics (only when physics or chemistry is a primary or supporting area), and physics will find these areas described under their respective departments. General Science and Physical Science curriculums are below:

General Science Primary Area (24 semester hours)

Required courses:

Chemistry 106--3 hrs., 106L--1 hr.; Life Sciences 102--3 hrs., 102L--1 hr.; Physics 106--4 hrs.; Geography and Geology 152--3 hrs.; 153--3 hrs. or 354--3 hrs.; 314--3 hrs. or 468--3 hrs. or 470--3 hrs. Approved elective--3 hrs.

General Science Supporting Area (18 semester hours)

Required courses:

Chemistry 106--3 hrs., 106L--1 hr.; Physics 106--4 hrs.; Life Sciences 102--3 hrs., 102L--1 hr.; Geography and Geology 314--3 hrs. or 315--3 hrs. or 468--3 hrs. or 470--3 hrs. Approved elective--3 hrs.

Students completing this primary or supporting area should elect Chemistry 105 and Physics 105 from the general requirements.

Physical Science Primary Area (24-28 semester hours)

Required courses:

Chemistry 106--3 hrs., 106L--1 hr. or 108--4 hrs.; 321--4 hrs. or 351--3 hrs., 351L--1 hr. and 352--3 hrs., 352L--1 hr.; Geography and Geology 314--3 hrs. or 315--3 hrs.; 468--3 hrs. or 470--3 hrs.; Physics 206--5 hrs.; 340--5 hrs.

Physical Science Supporting Area (15 semester hours)

Required courses:

Chemistry 106--3 hrs., 106L--1 hr.; 351--3 hrs., 351L--1 hr.; Physics 106--4 hrs.; Geography and Geology 314--3 hrs. or 315--3 hrs. or 468--3 hrs. or 470--3 hrs.

Students completing this primary or supporting area should elect Chemistry 105 and Physics 105 from the general requirements.

## Exhibit 3

### Mathematics Education Major's Requirements
### (Small Liberal Arts College)

In addition to general studies, a teacher education major is required to take the following program:

| Course Number | | | Semester Hours |
|---|---|---|---|
| Mt | 115 | Introduction to Computer Programming | 3 |
| Mt | 210 | Calculus and Analytical Geometry I, II | 4 |
| Mt | 211 | | 4 |
| Mt | 212 | Calculus and Analytical Geometry III, IV | 4 |
| Mt | 213 | | 4 |
| Mt | 310 | Abstract Algebra I | 3 |
| Mt | 320 | Geometry | 3 |
| Mt | 120 | Applied Statistics | 3 |
| or | | | |
| Mt | 370 | Theory of Probability and Statistics I, II | 3 |
| Mt | 371 | | 3 |
| Mt | 401 | Seminar I, II (Overview of Mathematics) | 2 |
| Mt | 402 | | 2 |
| Ed | 316 | Secondary Education (Math) | 2 |
| Ed | 417 | Student Teaching: Secondary | 6/8 |
| | | Note: In addition, students are advised to take the following courses: | |
| Mt | 160 | Applications of Finite Mathematics | 3 |
| Mt | 311 | Abstract Algebra II | 3 |
| Mt | 321 | Topology | 3 |
| Ed | 204 | AV and General Methods | 2 |
| Ps | 221 | Adolescent Psychology | 3 |
| Ps | 315 | Psychology Applied to Teaching | 2 |
| SEd | 310 | Nature of Exceptional Children | 3 |
| Ed | 323 | Group Tests Measurements | 2 |
| Rd | 318 | Reading Instruction in Secondary Schools | 3 |
| Ed | 316 | Secondary Education: 7-12 | 2 |
| Ed | 362 | Effective Classroom Teaching: Management and Multicultural Education | 3 |
| | | **Clinical Experiences and Human Relations** | |
| Ed | 100 | Introduction to Education and Human Relations | 1 |
| Ed | 200 | General Aiding and Human Relations | 1 |
| Ed | 300 | Specific Aiding and Human Relations | 1 |

Should we not examine the curriculum in light of building depth for the subjects to be taught? It seems important that the academic requirements for secondary teachers be reviewed toward recommending more emphasis on general science or mathematics courses and additional supervised classroom experience. We do not need to prepare all of our graduates to teach in a talented and gifted school or to teach calculus or advanced genetics; what we need are teachers who can introduce mathematical and scientific concepts to secondary school students and prepare them for more advanced collegiate work or to compete successfully for more technologically demanding jobs.

Schools of education are prepared to cooperate with others within the higher education community to consider the appropriate preparation of teachers. We would encourage the participants in this conference to recommend that some Federal dollars be set aside to accomplish this objective.

One option is to provide a series of modest discretionary grants to schools of education to stimulate faculty within education and departments of mathematics and science to develop the following materials: (1) viable recruitment strategies; (2) new curriculum for the preparation of middle school, junior high, and senior high school science and mathematics teachers; (3) accompanying instructional and/or software programs and materials; (4) inservice or staff development programs for practitioners in both subject matter and teacher education; and (5) faculty development programs to sensitize college personnel to these problems and needs. This type of grant program--with monies targeted to deans of education and deans of arts and science to be used for cooperative programs--could achieve major reform at modest costs.

Many schools of education have been forced to reduce faculty lines in science and mathematics education because of low program enrollments. Failure to generate sufficient credit hours warrants the elimination of courses and entire departments. Resources are needed to preserve faculty and programs in areas of low enrollment and high need and to support new or innovative programs that may initially attract small to modest numbers of students. In some instances, schools of education are also confronted with the problem of retaining high quality mathematics and science faculty who are now very marketable as industrial trainers at appreciably higher salaries. Finding monies to add to their salaries (for full-year employment) or to provide additional benefits is very difficult and may result in the continuing attrition of faculty in these areas of high need--a problem not given sufficient attention by those concerned with this issue.

Myth: A Single Solution Is The Answer

Reality: Different solutions are needed for different problems. For instance, the solutions that address the shortages of mathematics teachers at the high school level (i.e., finding technically and pedagogically competent teachers to teach high school calculus) are not the same as those that will alleviate the problem of inadequate mathematics education at the elementary level. Most of the solutions that have been posed in this and previous conferences have focused on the former problem (enlarged to include the problem of attracting physics and chemistry teachers) and have neglected the problem of dealing with the shortage of qualified mathematics and science teachers for the elementary grades.

Shamos (1982) reports that there are several studies that both document and address the problem of unqualified or underqualified elementary school teachers. He indicates that this is a particular problem because it is in the elementary grades that much can be accomplished. As Shamos notes, in the "formative elementary school years, when minds are so receptive to new ideas, and before their patterns of thinking have become fixed, it should be possible to develop a foundation in science that will remain a permanent part of the individual's intellectual life" (Shamos, 1982, p. 7).

Science education prior to the secondary school experience is critical because it provides the foundation for subsequent scientific understanding. Attention must be given to our elementary schools where boys and girls develop attitudes toward science, mathematics, and technology. A school's emphasis on mathematics and science is influenced by student and parental attitudes, as well as by district or State program requirements. We need to find ways to reinforce positive attitudes. Mathematics is "most popular" among 48 percent of third graders but declines to 18 percent in the 12th grade. Most students indicate that they do not see any real use for mathematics in their lives. Science courses are even more widely disliked, and the negative attitude is acquired early; by the end of the third grade, almost half of the students have no desire for more science, and that percentage is constant through the 12th grade (Forbes, Note 13).

Generally, lack of interest in mathematics and science is reflected by the quantity of school subject offerings. In the elementary grades, which have 25 hours of instruction weekly, less than 4 hours is devoted to mathematics and less than 1 hour to science (Forbes, Note 13). Consequently, the attitudes of today's high school students were forged over a decade ago.

The absence of qualified teachers at the elementary level presents a real dilemma to those who prepare teachers: to continue to prepare elementary teachers to be responsible for the total educational experiences or to prepare subject matter specialists for the elementary grades. Simple solutions will not resolve this dilemma. More creative ways are needed to help elementary school teachers gain competence and confidence for teaching science and mathematics and to support them, through appropriate means, throughout their careers.

School-based science specialists, system-wide curriculum supervisors, inservice workshops, equipment purchases, and curriculum development efforts are found in many school systems, but they are usually directed toward improving secondary school instruction. The success of such approaches has been varied, but little attention has been given to improving science instruction at presecondary levels. While it is hoped that some of the extended programs of professional preparation for elementary school teachers will address this problem at the preservice stage, better means of supporting the practicing teacher must also be found.

One idea that holds promise calls for the development of an interactive video capability and the parallel development of instructional units in science to "transport" resources into kindergarten through sixth grade classrooms via the new technologies. Teams of subject matter scholars, practitioners, educational development specialists, and production personnel could develop units in science. Through their efforts and available technology, teachers could draw on this data base to enrich programs and/or to provide direct instruction in concepts of science (Sandberg and Bosco, 1983). Such a practice could improve the ability of teachers to help elementary school children gain greater technological and science awareness during the formative years.

Both short-term and long-term strategies must be reviewed and considered within the larger context of ensuring competence and excellence of teachers. I believe that the concerns that we have argue for the need for a comprehensive personnel development policy that would ensure that preparation of sufficient numbers of qualified teachers to meet current and future demand--a comprehensive policy that would address recruitment into the profession, the quality of preparation, the nature of the classroom setting in which we place these teachers, the necessary support services for them, and retention in the profession. We need a national policy to be a model for addressing future personnel shortages in a rational manner. Collaborative Federal and State partnerships must be forged that will make the best use of combined resources in developing and implementing innovative responses to changing conditions in the profession.

## CONCLUSION

The shortage of qualified mathematics and science teachers is critical. Making do with an "almost qualified" mathematics or science teacher, reducing graduation requirements because student achievement has fallen, or introducing scores of remedial courses for college freshmen only compounds the problem. Shifting responsibility from elementary to secondary schools, from secondary schools to the colleges, from the colleges to the teachers, from the teachers to the nature of their working environment is no solution. We all share the responsibility; now it is time to identify integrated strategies and develop coordinated efforts.

## SUMMARY OF PROPOSALS

I propose that if we are to effect lasting improvements in education, we must engage in dialogue and research directed at the following goals.

Develop programs and techniques for the early identification of able students to attract them into teaching. Special attention can be given to attracting prospective teachers to areas of shortage and projected shortages. To accomplish this goal, it is necessary to enlist the support and efforts of practitioners, community and business leaders, and our colleagues in the arts, sciences, technology, and business on our own campuses.

Reexamine college entrance requirements and the general education components in light of literacy needs in other than the traditional ways. Some attention must be given to the literacy of the general public, rather than merely emphasizing courses and knowledge required for or leading to a major in the subject being studied. The expectation of the colleges for entering proficiency must be related to the necessary foundation for college study. General education, then, must be considered in light of the general knowledge that an educated citizen should possess.

Strengthen the support areas for science and mathematics. Science and mathematics cannot be studied in isolation. Knowledge of the humanities and social sciences becomes a tool for reasoning, communicating, and making ethical decisions. To ignore the relationships between mathematics and science and other disciplines deprives the engineer, the mathematician, and the scientist the breadth of knowledge necessary to become a fully productive and contributing citizen.

Change attitudes toward the study of science and mathematics. To emphasize the study of mathematics and science at the secondary school level to the neglect of the earlier grades may contribute to the negative attitudes and the element of fear of many young people toward these subjects. That fear and those attitudes provide a type of immunization for interest in the subjects. The anxiety, fear, and attitudes can be changed if concerted efforts are made to develop understanding and a conceptual framework on which to base the study of science and mathematics and to build confidence in the ability to learn, to deal with, and to work in these areas.

Encourage teacher educators to explore deviations from current patterns of teacher education to accommodate new needs and challenges. Some of the restraints to change in teacher education are imposed by tradition, accreditation, and certification. Authorization, recognition, and encouragement for reconceptualizing traditional practices used in the preparation of teachers can release the knowledge, the experience, the imagination, and the energy necessary to initiate new, exciting, and effective models. Consideration should be given to establishing a national academy or institute for the study of teacher education to reflect the strength of knowledge available concerning teacher education, to encourage research in the areas of teacher education, and to provide training opportunities for teacher educators.

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## DISCUSSION OF
## TEACHER EDUCATION: CURRENT CONDITIONS

James Kelly, Dean of the College of Education,
University of Pittsburgh

I feel obliged at the outset to express an extraordinary compliment to Dr. Anne Flowers for her willingness to address a topic of such enormous concern and consternation. The task is immense, ambitious, and challenging. It is as if one were pursuing the horizon or, to change the figure, trying to gather the ocean in a teacup. Although the effort may be thoroughly engaging--pursuing the horizon or gathering the ocean in a teacup--and exhilarating, it is unlikely to have salutary outcomes.

At first reading, the draft I had was about 40 pages long and in some instances my marginal notes far exceeded the text, which would suggest it was somewhat provocative. I was inclined to express my thoughts in the language of Plato's "Theaetetus." He said, "I am amazed when I think about such things. By the gods I am. I keep asking what things mean, and sometimes my mind almost becomes dizzy with the contemplation of them."

There are several difficulties in addressing myths, as Dr. Flowers has attempted to do. First, myths often arise because of at least partial truths. Some events and experiences created or contributed to the belief in them so that it takes careful analysis of the parts that are true, as well as the parts that are false, to dispel the myth effectively.

Second, a belief may assume the label of myth, not only by being false but by being widely believed. So as we address myths, we must recognize the necessity of unusually effective arguments to effect change in a belief system that has such wide adherence.

My concern is that Dr. Flowers' analyses of the eight beliefs she labels "myths" may not adequately address these two points. She rarely acknowledges the at least partial truth in the myth so the analyses are often incomplete, and the arguments used to dispel the myth often seem arguments designed for an audience that has already rejected the myth.

To put this another way, in giving only a one-sentence characterization of each myth, the author fails to explain the content and arguments of the myths she purports to dispel. This makes it difficult to determine exactly what is being refuted. And the refutations presented as reality are composed of fairly standard recitals of teacher education institutions' rationales for the most part. They do not adequately address the issues and problems of science and mathematics teacher preparation.

The proposals at the end seem to have no apparent connection with the myths and realities surveyed in the body of the paper, and several of these sound good but seem to be rather shy of meaning.

A second observation: As stated by the author, the problems confronting teacher education and the preparation of teachers are complex and cannot be resolved in simple ways. Yet the author goes on to be prescriptive in areas where flexibility and alternative actions appear to be feasible.

Although some problems are national, the solutions in most cases must be regional or area-specific. For example, our area, Pittsburgh in Pennsylvania--Pittsburgh is losing population while the Southwest is growing. Some areas have high unemployment, even among the educated, while others have stable and growing employment. And some areas or districts have older teachers rapidly moving toward retirement, while others have very young teachers looking for other options.

The problem posed is real. The solutions based upon the author's perceptions appear as partial and limited. Yet the author has set forth a set of ideas which can be examined, revised, expanded, and clarified. These tasks would be helped immeasurably if more informed by a more complete grasp of history and the relevant research literature. This is a strong bias of mine, the necessity to put things in historical perspective.

Albin Dunes Winspear, when he was at Wisconsin, wrote a book, The Genesis of Plato's Thought, and he began the book with a statement from an anthropologist, E.B. Tyler. It is an awkward sentence:

> To ingenious attempts to explain in the light of reason that which needs the light of history for its full meaning, much of the learned nonsense of the world has indeed been doomed.

I think the insight of E.B. Tyler's is one that we can honor in our own investigation, the necessity of putting things in some historical perspective. The author seems to believe that remedies tacked on from outside can produce fundamental changes in schools, a notion which is largely unsupported historically and unsupported empirically.

For 2 years, from 1966 to 1968, Dick Lawrence and I ran a think tank, a National Institute for AACTE in the Office of Education. And after 2 years I wrote up some of our findings. One was that national experts and national programs have little impact on local programs because the local experts see to that. The second observation I would share is that we discovered the inexhaustible capacity of an educational bureaucracy to absorb many innovations without changing a thing.

So I do feel compelled to try to put things in historical perspective because I think it does make for some economy in terms of our inquiry and research.

There continue to be discrepancies in access to knowledge and in the quality of instruction. If you see Opopkovitz on the myth of educational reform, I think there are some very clear reminders of that.

From the mathematics, natural science, and social science curriculum reform efforts of the 1950's and 1960's, for example, we should have learned of the myth of supposedly teacher-proof curricula, with or without benefit of computers, which unfortunately are often used as $3,000 worksheets.

Good teaching involves more than knowing your subject matter in terms of credit hours accumulated. Questions that might be well raised and addressed here include knowledge of what subject matter, and how the desired mathematics or science could best be taught.

In this regard the paper does not acknowledge relevant research in cognitive information processing, science education, and teacher education, such as that of Smith and Anderson at Michigan State or the work that is going on at Wisconsin. And I certainly feel obliged to mention what is going on at the University of Pittsburgh, especially in the Learning Research and Development Center by Greeno and others, much of which is supported by NIE.

A third point, the author's tendency to overgeneralize, particularly to overstate claims, is disturbing, as is the absence of clear relationships between the myth problems and the proposed solutions.

Now, to myself I made a gratuitous observation, "Although hyperbole is an acceptable literary tool and device, it tends to generate problems and ambiguity in professional discourse and scientific inquiry."

While the proposal to encourage teacher-educators to explore deviations from current patterns of teacher education and to accommodate new needs and challenges seems intriguing, it is the fact that the initiatives iterated are unlikely and suggest little substantive basis that gives me considerable concern. And to ask for money without indicating how it is to be spent and providing evidence that such use is likely to have the desired effects seems inappropriate and certainly not convincing.

The author implies that while teacher educators are not responsible for the problem, they can, given enough money and freedom, provide solutions. To me this is undisciplined optimism and I don't find the assertion very compelling. In fact, I am uncomfortably reminded of Arthur Wise's "Legislated Learning" and his notion of hyperrationalization.

While the paper might appeal to some teacher educators, it is not likely to be received well, I think, by researchers, and it would seem to provide a somewhat easy target for teacher education critics. Their number already is legion, and I have no desire to increase it.

The thing I do want to conclude with, and Jerome Bruner is the last person for whom I usually reach as a source to quote, is from his "Education Revisited," where he comes out as the new Bruner and says:

> The reform of the mathematics is not enough. The reform of the schools is not enough. The challenge of man is to produce a civilization that cannot only feed him but keep him caring and believing.

Now, that's the note on which I want to close.

Judith Lanier, Dean of the College of Education,
Michigan State University

In general, I certainly agree with both Anne and Jim in the sense that myths are in fact unproved collective beliefs, beliefs that are accepted uncritically, and thus lack foundation in fact. But at the same time, these same myths do emerge and acquire form and credibility because they have these dimensions of reality embedded in them. In fact, the myths are rooted in culture and are complex in nature.

The analysis of myths, then, it seems to me, for purposes of identifying elements of reality, or aspects in need of further research, must also be complex and culture-specific. Thus I share a substantial amount of Jim's reaction to Anne's paper in the sense that the myths and the comments on them tend to be so broad and sweeping that it makes it somewhat difficult to tease out the partial aspects of reality or the unexamined questions that might be associated with them.

But I think we have to acknowledge the difficulty of identifying myths about teacher preparation. Whether it concerns the teacher shortage in science and mathematics or not, it's a difficult one. And I think the difficulty emerges in part from the need to address national concerns that have a modest consensus, while we realize simultaneously that most generalizations can be contradicted with specific exceptions at local and regional levels.

So the task is fraught with the inherent challenge, I think, of making general statements that are characteristic of many, though clearly not all, persons or programs or institutions that are concerned with teacher preparation.

I have the same kind of concern as Jim did with the paper, in the sense that we take a myth and talk about it in terms of all or none in total, as opposed to most or some in part. For example, "The schools are failing" issue. I think this statement is too general and in need of greater specificity.

To say that the schools are or are not failing in general is not to get us into a "Yes, they are," "No, they are not" argument, but rather to state that it is the case. In certain areas we have major problems, and the problems we have are a function of the failure to achieve some important goals at the level and in certain fields that we would hope to do better with in the future.

This area of science and mathematics is one that I think we need to look at squarely and publicly acknowledge particular failures that we might be having in this or that regard. At the same time, I think we need to acknowledge the strengths that the schools have had, the successes they have had as well as failures. But I think we shouldn't do that by turning our backs on the persistent problems.

My concern with the other myths are also similar. They lack explication of the complexities. For example, there are too many teachers already in certain fields and certain locations, and there are too few in others. This situation is not new. In fact, we have had a shortage of physical science, chemistry, physics, and mathematics teachers since 1939. But the magnitude of the problem has changed. We must ask what has been done or might be tried by teacher preparation institutions that will help alleviate this continuing long-term problem.

The myth that teacher education students are not very smart has grown in acceptance, as we know, and a number of studies have clearly demonstrated that some of them are lacking in important basic skills, subject matter knowledge, and teaching competence. Thus, I think we ought not argue that teacher education students or graduates are sufficiently smart in general terms, for some are and some are not.

In my view, some of the critical questions here include: How can we come to make important judgments concerning knowledge and skill sufficiency? What is quality? What constitutes it? On what grounds? And what are some sound means of making needed discriminations between those who have sufficient preparation and those who do not? And what we should ask is: What has been done? What can be done on the part of those who prepare and hire teachers in this regard?

The myth that teacher education programs are academically substandard is not treated well in general terms, either. For some teacher education programs likely are substandard while others are not. The question is again one of making needed discriminations between those teacher education programs that have made or are making significant advances in preparing qualified teachers and those that are not. Related questions there concern the adequacy of program resources for quality preservice as well as inservice teaching and learning in science and mathematics.

The myth suggesting the general beliefs that certification waivers and additional salary would assure good teachers is somewhat questionable. Why? Because in general it is assumed that these strategies could help alleviate the teacher shortage. But I don't think it is widely accepted that these changes alone would guarantee quality.

One particular hypothesis did emerge in Dr. Flowers' discussion that was clear and provocative, and since I have major disagreement with it, I thought I would give it some focused attention for the remainder of my remarks.

When challenging the myth that teacher education students spend too much time in professional education courses, Anne questioned the level of the depth of the scientific and/or mathematical knowledge needed by the secondary teacher. She implied, in fact, that deep understanding of mathematics and science subjects could have unintended deleterious consequences. Her reasoning seems to be this: that the possession of advanced knowledge in these subjects creates a kind of enjoyment and need of intellectual stimulation, a form of enjoyment and need that may be subject-specific and thus frustrating to the mathematics or science teacher when teaching lower levels of these subjects to high school students. Thus, she recommends a possible reduction in the depth of subject-matter knowledge required of prospective teachers since it may not be directly applied to teaching high school algebra or biology.

I take strong issue with this view because my experience and my general belief is that teaching can be, and often is, an extremely stimulating intellectual activity that is enhanced when a person has a deep and sound grasp of the subject matter, even when teaching the lower level courses. But what is important, I think, is that these differences of opinion cannot really be fruitfully discussed without the further knowledge and insight available through research.

Both philosophical and empirical study is needed if teacher educators, like Anne and Jim and me, are to become better informed about what are probably no more than partial truths associated with our respective views.

In fact, when I was first reading this particular issue in the paper, I was reminded of a meeting I attended at the Teacher Education Council at Michigan State. The mathematics department had proposed as a requirement a fourth course in calculus. We, on the other hand, were saying, "Well, the major evaluation and followup studies of our graduates in mathematics do not indicate they really feel they need more mathematics but that they are having most difficulty teaching their general mathematics students in ninth grade, and they're saying, 'You didn't prepare me for this.'"

So whether there should be more or less is a question of great importance that needs to be studied if we are to get this beyond a "Yes, you do," "No, you don't" kind of argument, which is about where we are now, in my view. I think it is high time that we increase our research activity and decrease our assertions about the effects of differential subject-matter knowledge on the quality of teaching and learning.

Related to this issue is another myth we have heard talked about here at the conference, which is that elementary school teachers do not have sufficient knowledge of science and mathematics in their teacher preparation in order to do it well. Evidence suggests a number of negative attitudes and misconceptions about science and mathematics are acquired by students in the elementary school years and the possibility--or let's think about it as a hypothesis--that elementary school teachers who have a stronger and deeper grounding in the concepts of science and mathematics might be more successful. I think that should be thoroughly examined in a number of approaches.

In terms of the secondary teachers--I'm talking about the subject matter for prospective teachers that need more reality testing--the secondary science and mathematics teachers do not appear to acquire sufficient knowledge about pedagogy, learners, and learning in their teacher preparation to teach it sufficiently well.

I think the secondary teachers generally find studies in their major rewarding, relatively easy to master. We know they have particular difficulty in teaching it to youngsters who do not find the subject quite as readily understandable or as intrinsically rewarding as they do. And so I am suggesting that teacher preparation programs at the elementary and secondary levels might be adjusted in these ways, increasing knowledge of the subject for the elementary teacher, and increasing knowledge of pedagogy for the secondary teacher, and then pursuing inquiries into the subsequent effects on teaching practice and student learning.

Another approach that I think deserves serious consideration concerns the rewards of teaching itself. Increased pay for science and mathematics teachers or tuition waivers for their preparation if they teach in elementary and secondary schools for a number of years is, I think, important in terms of recruitment and retention of talented persons. We should explore and proceed with those possibilities. But I think in the long run financial rewards may not be sufficient--necessary, perhaps, but not sufficient--and one of the most important rewards in teaching will perhaps be overlooked if we do not seek to better understand these rewards in general.

There are indications that some of the most powerful rewards in teaching are, in fact, associated with learner achievement, that is, when the learner's achievement is a clear consequence of the teacher's instructional efforts. Could teacher preparation programs help prospective teachers to think about and come to value such rewards? Do some persons enter the profession because they already value these academic and humanitarian outcomes?

I think about the athlete who after years of success and enjoyment playing the game becomes a coach and comes to find that the winnings and achievements of others are rewarding. Teacher preparation programs help the prospective science and mathematics teachers who genuinely enjoy playing the game, particularly those at the secondary level, come to find the achievements and the winnings of others as rewarding and as intellectually challenging as the coach.

Even so, it may take new approaches to both preservice and inservice teacher education. If these potentially important rewards in teaching are to be realized, I think we need further reality testing and research on the rewards of teaching itself which could lead to some fruitful means of attracting and keeping talented science and mathematics teachers for whom monetary gain is not necessarily the single or the highest good.

Since it is not only myth, however, but safe to assume that teachers cannot teach what they do not know, it is critical, I think, that we gather more information on the nature and the level of science and mathematical knowledge that teachers now have--especially those who are teaching these subjects on the basis of neither a college major or minor.

In the 1981-82 school year in Michigan, for example, more than 36 percent of all the junior high school mathematics teachers were teaching without a mathematics major or a mathematics minor. And for two-thirds of that set, mathematics teaching was the primary assignment.

In addition to finding some means of acquiring and studying such data, I think we need policy studies of State and local school board decisions, collective bargaining issues, and recommendations from organized teachers as they relate to the ethical and academic judgments, recommendations, and standards that they hold in regard to teacher certification, qualification, and assignment in science and mathematics teaching.

I think that our Nation has an obligation to its citizenry in general and to parents and children in particular to monitor and make public the standards of quality that are being held for the elementary and secondary teaching force in this Nation. It also has a responsibility to continuously study and describe the potential consequences to students and teachers of any modifications in those standards.

Finally, I think research is critically needed on teacher education and the teacher education programs in the institutions themselves. As we all know, these folks have been the whipping persons of public and professional myths for generations. I think we need to better understand the curriculums that they offer, the financial and institutional characteristics and constraints that they face, the [illegible] the teaching that they afford, and the qualifications of the student body that they recruit, prepare, and graduate.

What I am saying is that many of the problems that we face and many of the different viewpoints that we hold about teacher preparation may be most appropriately resolved by increased understanding and knowledge. I think research is obviously needed if we are ever to distinguish myths from realities, and that teacher education, like teaching, is often the scapegoat for those who are impatient with our Nation's educational progress and problems.

There is a paucity of research in teacher education and a mountain of myths about it. And it obviously needs more thought and better understanding on all our parts.

Commentary: Dr. Lee Shulman

Continuing with my attempt to relate some of this to a research agenda, I will make a couple of brief comments before turning it over to the third discussant this morning. As you know, there is very poor, if any, empirical evidence regarding the relationship between how much teachers know, as represented by their test scores in some areas, and the changes in test scores produced in their students. I think the character of that research suggests that it probably is the wrong way to ask the question.

But there has also been some research that attempted to identify what kinds of difficulties are associated with teachers who lack certain kinds of depth in their subject areas. One of those sorts of difficulties seems to be particularly provoked in the kinds of settings where kids do a great deal of independent discovery activity and are thus highly likely to come up with unpredictable, unexpected reformulations of the material being taught.

There was a dissertation at Michigan State by Jan Shroyer that identified similar problems, asserting that in many ways the best defense against unpredictable, though often creative and inventive, responses by students was a form of instruction that accepted no unusual student responses. We call that teaching style the Admiral Farragut style of teaching, "Damn the torpedoes; full speed ahead!"

We had some case studies of teachers who varied in that way; and the depth of their knowledge seemed to be one of the reasons they taught in a particular fashion.

Another observation, Judy, would be that I think we not only have to ask the question, "Do we need more or less?" but, "How should it be organized?" I think it is quite conceivable that we don't need any more, but that the curriculum in mathematics or science that the folks in those academic disciplines provide is not organized in a manner that is appropriate to the preparation of teachers.

I also have a hypothesis which I think I shared with you yesterday, and that is that the curriculum in mathematics or science, if properly understood, is not well organized for the teaching of mathematicians, either. If that curriculum were reformulated so as to be organized in a teachable way, it would also be much more comprehensible to people majoring in mathematics or the sciences than it is right now.

Odus Elliott, Associate Director for Academic Programs,
Arizona Board of Regents

After listening to all of the articulate presentations yesterday and again this morning from people who are very well grounded in research and practice in the areas of teacher education and mathematics and science education, I must agree that Lee's characterization of me as a civilian is probably pretty accurate. A term that would perhaps be a little more accurate is "amateur."

There are a couple of advantages to being an amateur in a crowd like this. For example, most of the time an amateur is a little more easily forgiven for his shortcomings and oversights in his presentation. Secondly, he is often allowed to be a little more pedestrian in the types of things that he says. So I hope you will keep those things in mind for me as the civilian member of this panel.

As Lee mentioned, the perspective that I bring to this conference is that of one segment of the State-level governance structure of our diversified and highly decentralized system of education in this country. By "governance structure" I mean governance units such as the State legislature, the Governor's office, the State board of education, higher education governing boards, higher education coordinating boards in some States, and even local district governing boards.

With this kind of perspective and background, I read Anne's paper a little differently from the other two discussants. I viewed her paper not as an attempt to provide a definitive philosophical, polished statement about teacher education, but more as a vehicle for this conference to begin to identify some of the major problems that we see and that we face in this area of teacher education.

John Taylor called last fall and asked what we were doing out in Arizona in the area of teacher shortage in mathematics and science. I explained to him that his call was very timely because a few days prior to his call Governor Babbitt, who was at that time running for re-election, had issued his platform concerning education issues in the State. And his platform went something like this:

> We need to increase the university admission standards to require students to have more mathematics and science in high school.
>
> We need to establish summer programs at the universities for high school students who are gifted and talented in mathematics and science areas.
>
> We should establish a student loan program for prospective teachers and waive repayment obligations if those teachers go on to teach in elementary and secondary schools in the State.

He said, "Let's form summer institutions, mathematics and science institutes, to allow our teachers to upgrade their skills and to allow retraining of teachers who want to enter those specialties."

He said, "Let's change our teacher certification requirements to require computer literacy along with other aspects of teacher preparation."

He said, "Let's establish a pilot program for increasing the compensation of science and mathematics teachers in selective districts across the State."

These are not new ideas for most of you. They are not innovative ideas. But I think the Governor's recognition of the problem is what is significant in this anecdote. It was important enough to him to make it one of his major campaign issues last fall.

The other candidate for Governor didn't have such an educational issues component in his platform. Governor Babbitt was re-elected by a very large margin.

I am not sure we can conclude from that that he has a strong mandate to bring about his programs in education, but that may certainly have been a part of his success. It is also significant because, as a followup to his election, the Governor has recommended for the 1983-84 budget that $500,000 be allocated to begin to implement and initiate some of these programs.

That is not a lot of money, but looked at in perspective of what is happening in Arizona and what is happening in a lot of other States, it is a significant development. Why? Because he is recommending for most State agencies a substantial reduction in their budget for 1983-84, a level below their current year's budget. To be proposing a new program in the area of mathematics and science teacher training and education, I think, reflects his view that this is indeed a vital area.

After all the discussion yesterday about the shortage and about the problems in mathematics and science education, I assure you it's a real pleasure to offer this note of optimism and encouragement as one State begins to deal with this problem.

I would like to offer just a few comments about some of the points made in Anne's paper. In the identification of the problem, I think I would place a little more emphasis on the economic foundation of the problem. It was alluded to by a couple of the speakers yesterday. Industries in this country have not kept pace with industries in other countries in high technology areas. Consequently, our industries are suffering, they are scrambling, they are trying to catch up, they are being affected in the marketplace. Consequently, those businesses and industries are raiding our schools for employees and at the same time are demanding graduates from our school system who are highly skilled in mathematics and science.

I think this is one of the major reasons this problem has gotten the attention of many of the political leaders or at least some of the political leaders in this country. They recognize the importance of having well trained human capital to rebuild the economies, both of the State and of the Nation.

Anne suggests that it's time for change, and I think many are beginning to agree and to support that argument or point. Some of the organizational change studies I have seen have concluded that often changes occur in organizations because of outside pressures and forces or because of top-down kinds of mandates within the organization.

I think this is one place the governing structures of our education systems can contribute to the solution of the problem. They can become a part of that outside force that keeps this issue in the forefront and that continues to place pressure on our diverse and decentralized system to grapple and to deal effectively with this problem.

The problem is exacerbated by the decisions of some of our governing boards to increase high school graduation requirements in mathematics and science, and also to increase admission requirements for our colleges and universities. As we begin to say to the high schools, "You've got to give students more exposure to mathematics and science subjects," those high schools are faced with the frustration of wanting to do that but not having adequate numbers of well prepared teachers to respond to those outside pressures.

One of the myths Anne mentions is that certification waivers will bring good teachers to the classroom. Several people have already addressed some of the problems that arise as a result of giving certification waivers to people who may not perform well in the classroom. Waivers are certainly not the best solution, but they may be a necessary interim measure, at least until we can figure out ways to improve the productivity of the teachers we have or increase the number of teachers available. Waivers should be temporary and they should also require some type of intensive training in pedagogy to strengthen people who do not have adequate preparation in that area.

While we have heard a number of criticisms of the teacher certification waiver movement, I have not heard very many suggestions from the program presenters about what the schools are going to do if they don't get waivers for individuals who may have some skill and some ability in mathematics and science.

A frequent complaint that I hear from people who have graduated from many of our teacher education programs is that there is too much duplication in the content of teacher education courses. They said that it may be possible to provide students with the necessary skills in less time and in fewer education courses if we take a close look at the possibility that we may be duplicating some of the content in those courses.

In Arizona the State Department of Education has launched a statewide project to identify precisely those skills that are needed by the classroom teacher, and that project has included a great deal of participation by teachers in the State. The goal is to revamp certification requirements in the State to focus on specific skills, rather than on having completed certain traditional courses that we find as a part of most of our teacher preparation programs around the country.

Another myth is that if we pay more, we will get the teachers. Teaching is a profession that requires a commitment to values other than materialistic values. We must make it possible, however, for those who do have the value system, the skills, and the commitment necessary for effective teaching to maintain a reasonable standard of living. And I think we can begin by improving the salaries for mathematics and science teachers as one of the strategies for eliminating the shortage.

Now, this may require an increase in taxes; and that is a hard pill to swallow for people who are responsible for making decisions about taxes. But given the condition of our economy in most of our States, it is not likely that State revenues and local school district tax structures are going to generate the tax revenues that are needed simply as a result of economic growth, at least not during the next couple of years. I hope I'm wrong. I hope our economies turn around fast enough and that our systems of taxation will generate more dollars based on economic growth, but that may not happen. A considerable amount of courage and foresight would be needed by our elected political officials to come to grips with that problem and look at the possibility that we may need to either reallocate from existing government services or programs or increase taxes to generate the revenues necessary to bring about changes.

Now, I would offer a more encouraging word about this teacher supply problem. An associate dean of one of our colleges of education in Arizona told me last week that he is beginning to see a few students from other programs in the university transferring into teacher education programs, several from engineering programs. He went on to explain that these are not students who are flunking out of the engineering programs, they are not students who are having academic difficulty over there, but they are students who have concluded that a career in education would be much more personally fulfilling and rewarding than a career in some engineering discipline which they had earlier decided to pursue.

That is an encouraging word, and I would be interested to know if anyone else is beginning to see any kind of flow like that between the other academic programs on campus and teacher education programs.

Another myth is that teacher education students spend all of their time in professional education courses. This has already been alluded to so I will not spend a great deal of time talking about the level to which teacher education students should gain competency in their particular discipline. But I would add just a couple of things that concern me as a civilian or as an amateur in this field. I wonder if a teacher who has not completed advanced courses can fully appreciate the significance, the importance, and the relevance of the basic courses in mathematics to the advanced courses. And I wonder if they are not more effective teachers if they have a good grasp of the relevance and the relationship between the various levels of mathematics.

Another comment that I do not think was made earlier on this topic is that we may be doing a disservice to the teacher education students if we do not encourage them to go on and attain higher levels of competence in their field, whether it be science or mathematics. The reason is this: They may not be teachers all of their working lives, and if we do not encourage them to attain a high level of competence in their specialty, we may be encouraging them to put a limit on the other types of career options they may have after they decide to move on to some other type of career.

One of the proposals that Anne made near the end of her paper was that we need to give more emphasis to the support areas in mathematics and science. I would like to add my endorsement to that. I think it is very important that in our teacher training programs in mathematics and science we make sure that the students have adequate exposure to English and humanities. They need to be able to use the language clearly and to communicate effectively if they are going to be good teachers. And they must have a sensitivity to ethical and humanitarian concerns that may arise from scientific disciplines and scientific study.

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Finally, I have a comment about the potential role for a State-level governance in the strategy for addressing these problems in mathematics and science. As I mentioned earlier, the governance structure includes the governor, the State legislature, and various governing boards in the fields of education. I think there are four or five types of activities that the governance structure may examine as part of their contribution to the strategy for dealing with these topics.

Most of the governing boards, at least, and to a certain extent other units of governance structure, have a role of setting missions and priorities for institutions within their domains. I think they can look at the needs in this area as they are examining what are appropriate missions and roles for their institutions. They also have a responsibility for oversight. They can press for curriculum and program review that may be needed in these areas.

In a third role, governing boards can serve as advocates for funding improved teacher education programs with a State legislature.

Governing boards and governance units seem to have a little more ready access to the media, to the press. They can continue to give visibility to these problems and to possible solutions to those problems.

Finally, I think the governance structures have a major role to play in coordination. It has been emphasized several times during our conference that the problem before us is a complex one and requires cooperative efforts by a wide variety of actors. I think those governing units who are responsible overall for the governance of the system can make sure that there are ways in which the various units involved in this program or in this problem can coordinate their efforts and deal with it in a very systematic manner.

## OPEN DISCUSSION

DR. SHULMAN: I remind you, Odus, that another meaning, perhaps the original meaning of "amateur," is someone who does the work for the love of it. I hope in that sense all of us are amateurs in the field of education and teacher education.

One observation I would make, provoked by your comments: I am concerned, and I hope you will reflect for a moment, and some of my colleagues in the profession who may share your perspective will reflect, on what may be a fundamental contradiction in your simultaneous call for greater depth of understanding of subject matter on the one hand, and then a definition of teaching in terms of a set of skills on the other.

I find it remarkable that behaviorism is dead and almost buried in psychology but is so alive and well in the halls of policy. It would be a little like setting astronomical policy by mandating epicycles.

This is a very controversial issue, and I think the weight of the evidence in the research suggests we ought to be terribly careful about--and I'll use an emotionally laden word--trivializing the work of educators by defining what they do in terms of a set of observable skills, when we would never ever dream of defining the work of a mathematician in terms of a set of observable skills, or that of a physicist.

I think the evidence we have is that these are not particularly fruitful ways of defining teaching competence, and they certainly do not define the kind of competence that will lead a person to grow in the job, which is precisely the rationale for having them have deeper knowledge of subject matter.

DR. LANIER: Because this is such a critical issue, I want to say that one of the reasons, in my view, that teachers are leaving teaching is that we have cast teaching as technical work and technical activity with skills, as opposed to professional work that requires the exercise of important cognitive judgments. I think that kind of view may well be inadvertantly driving people from the teaching force, because teaching is seen as technician-type work, not professional work.

DR. FLOWERS: First of all, I want to say what a pleasure it was to find that the first two discussants employ the same type of objectivity that I did.

I would like to clarify one area that I perhaps did not present as well as I should have. As we are talking about the depth of understanding of subject matter, I am talking about a reorganization, a change in the curriculum for teaching, and for us to know the kinds of things we are going to be teaching youngsters, rather than extreme emphasis on research or very heavy types of sciences as they are now organized in science departments. And that is a different kind of thing, and perhaps my presentation was not clear.

DR. TALLEY: Dr. Flowers mentioned a very concrete suggestion and it was picked up by Dr. Elliott who had a counter, "raise taxes." Dr. Flowers suggested that the salary differential be made up by part-time employment of qualified people by industries and listed a number of benefits that would flow to the students, to the teacher, to the school system, and to the taxpayers, but unfortunately I didn't hear what the quid pro quo for the business would be. And I am wondering if, other than being a corporate good citizen, which unfortunately won't make the stockholders too happy, she or any of the representatives of industry in the audience have thought about the benefits to the company which gives up full-time employment of what we would imagine to be a very valuable employee.

DR. FLOWERS: I think, one, it could enlarge the pool for the industry or for the business itself. Another, of course, could be a tax incentive if that sort of thing was built in.

DR. TALLEY: Enlarging the pool again benefits all the companies, and the stockholders want the officers of the company to make profits for them, not for all automakers rather than General Motors. But other than tax incentives, does anybody have any idea about how the companies could benefit?

DR. SHULMAN: Is there someone from industry who would like to respond?

MR. BUESCHER (Jim Buescher, ALCOA): In response to that statement, I guess the issue for us from industry is really a longitudinal one. Assuming that we are not in a liquidation process--and I hope we are not--we are going to need qualified graduates today, next year, 10 years from now, 20 years from now. And if the school systems are not providing those, then obviously we are going to have to get involved--and we are, because we have that concern.

So if it means employing a teacher for the summer, call it an outreach effort, if you will. Trying to measure it from a stockholder's standpoint may be a little difficult, but we think the issue is much broader than this quarter's profitability.

# SESSION VI
# SCHOOL SYSTEM RESPONSE TO THE PROBLEM OF TEACHER SHORTAGE IN SCIENCE AND MATHEMATICS

## THE TEACHER SHORTAGE IN MATHEMATICS AND SCIENCE: THE LOS ANGELES STORY

Rosalyn Heyman, Assistant Superintendent of Secondary Education,
Los Angeles Unified School District

For the past several years, the shortage of qualified mathematics teachers has been severe; for the past 2 years, the shortage of science teachers has become a serious concern. Among the factors contributing to the shortages are:

- increasing numbers of teachers, especially in mathematics and science, are leaving the classroom for higher paying jobs in government and industry. Some private corporations attract teachers becaused they offer the added benefit of paying for college and university courses leading to advanced degrees;
- a declining number of college students are pursuing teaching careers in every subject field. Among the 1982 entering freshmen at U.C. Berkeley, less than 1 percent specified an interest in teaching;
- increasing numbers of mathematics and science teachers are reaching retirement age;
- many housewives with teaching credentials who could have been attracted back to teaching in times of emergency are already employed full-time in the work force.

In order to teach in a public school in California, a teaching credential (license) is required, which is authorized by the California Commission for Teacher Preparation and Licensing. Full credentials are issued, upon recommendation of a college or university, to teachers who have successfully completed the required courses in their subject field and in education and who have completed a student teaching assignment. In order to help solve the teacher shortage problem, the Commission issues emergency credentials for the current year only to applicants that the District finds promising and is willing to hire. Mathematics and science emergency credentialled employees have varying degrees of preparation--some with basic credentials in nonshortage fields, but most with no credential at all. Therefore, holders of emergency credentials must, while they are teaching, complete some university course work and pass necessary examinations in order to obtain a full credential or to have their emergency credential renewed for a second year.

One measure of the teaching shortage is the number of emergency credentials issued to teach mathematics and science. In the 1980-81 school year, within the Los Angeles Unified School District (LAUSD), 169 emergency mathematics credentials were issued; in the 1981-82 school year, this number rose to 333 in mathematics and 82 in science. In addition, the District granted another 157 limited assignment permits to teachers with credentials in other subjects so that they could fill in and teach one or more mathematics or science classes. In 1982, the figures climbed to 508 emergency mathematics credentials and 89 emergency science credentials.[1]

Large numbers of these teachers lack adequate preparation. For example, of the 1,444 teachers teaching one or more mathematics classes in secondary schools in 1981-82, an informal sampling revealed:

38% were mathematics majors (547 teachers)
30% were mathematics minors (436 teachers)
32% were neither mathematics majors nor minors (461 teachers)

Last September, the District was able to open school with a contract teacher in every classroom for the first time in 12 years. This result came about in large measure because of the difficult economic situation. During that past summer, the Personnel Division interviewed hundreds of applicants, many of whom applied because they were unable to obtain employment in government or industry.

The shortage will, however, continue to grow for these reasons:

- as economic conditions improve, many teachers will return to the higher paying jobs in government and industry;
- increasing numbers of mathematics and science teachers are reaching retirement age;
- State and City Boards of Education are proposing increases in the number of years of mathematics and science required for graduation from high school;
- universities and colleges are increasing entrance requirements.

As requirements are increased, shortages become greater. To add one-half year of mathematics would require 121 more mathematics teachers; to add 1 year of science would require 162 more science teachers.

What has been done to solve the problem? A review of the past 20 years is in order.

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[1]Of the 508 in mathematics, 300 are full-time mathematics teachers; of the 89 in science, 70 are full-time science teachers.

## The Cuban Crisis

In the 1960's, the Cuban crisis brought many learned refugees to this land--mathematicians and scientists, university professors and school teachers. Representatives from the District went to Miami to recruit. Preliminary credentials were issued which allowed these professionals to teach while attending required university classes in the evenings and on weekends. The university classes coupled with the on-the-job training that each school provided were not enough to hold many of these teachers. The honor and respect given the teacher or professor in Cuba was not found in the junior high schools of Los Angeles. Those who were most successful were alert and perceptive in the classroom and well enough organized to readily implement the classroom management techniques they were being taught at the local school. Many left teaching; those who remained have continued to provide excellent instruction for young people; several have become highly respected counselors and administrators.

## The Engineer Layoffs

In the early 1970's, when the defense contracts in the Los Angeles area were moved to other parts of the country, industry was compelled to lay off hundreds of engineers. These massive layoffs provided the District once again with a source of personnel willing to teach mathematics and science, and the District recruited large numbers of them. The District gave them jobs, helped them obtain the preliminary teaching credential, made the arrangements for them to enroll in a university or college to complete the necessary coursework in education. On-the-job training was provided by the District and the local school, and the college or university also offered some supervision of instruction. As with the Cuban refugees, the engineers were unprepared for what the junior high school had to offer. Many soon discovered, or rediscovered, why they had chosen not to teach in the first place. Teaching is difficult. The engineers, like the Cubans, were very knowledgeable in their subject area, but were not able to apply effective teaching and classroom management techniques and did not have any background in learning theory. Large numbers left the profession before completing their training; many more left as soon as industry started rehiring. The few who remained are doing an excellent job.

## Summer Programs

In the late 1970's, the District started summer programs to retrain substitute teachers, elementary teachers, and secondary teachers with credentials in other subjects. The Commission for Teacher Preparation and Licensing created a credential for these people to obtain--the Supplemental Authorization Credential. A teacher with a credential in another subject could take 30 quarter units in specified areas of study, such as mathematics or science, and obtain a supplemental credential. For the mathematics authorization credential, 1 year of college calculus is included.

One of the District's first efforts was a 6-week summer workshop taught by an experienced District teacher. The teachers attended for a full day for 6 weeks and were paid a stipend. The dropout rate was high, but those who did finish stayed with teaching.

In the 1970's, science teachers regularly participated in NDEA workshops offered through the colleges and universities. These workshops helped teachers update their knowledge and skills. Much of the funding for these fine science workshops is no longer available.

Internship Programs

Two years ago the District contacted the Commission for Teacher Preparation and Licensing and asked for permission to institute a number of experimental internship programs. The request was granted. The District held a consortium of all the local colleges and universities and approached them with the idea of providing internship programs for District employees who wanted to change their credentials to add on mathematics or science. In conjunction with this, the District created an advisory board which included mathematics and science teachers selected by the teachers' union. As the colleges and universities submitted their proposals for experimental internship programs, the advisory board made suggestions and ultimately approved each one and sent it on to the Commission for Teacher Preparation and Licensing, which granted final approval. Some were successful; others were not. Some of the colleges and universities had tuition fees that were prohibitive for working teachers, and the District was not in a position to help financially. There was great interest in these internship programs in the Spring of 1980, when the District had announced a large teacher layoff slated for June. When June came, the District did not have to go through with the layoff, and so interest in the internship programs declined.

The next step was to provide programs for teachers holding emergency credentials to get full credentials. The same pattern was used. The universities and colleges were contacted and made aware of the needs of the teachers. They all cooperated and offered to provide appropriate summer programs. The District then compiled a list containing the name of the university or college, the contact person, and the telephone number. This notice was sent with a personal letter to every teacher holding an emergency credential, urging that teacher to contact one of the schools to enroll in a training program leading to the full credential. This program was very successful and is being repeated yearly.

The latest District effort has been to embark on a joint university/District internship retraining program to train mathematics teachers. UCLA was selected, primarily because it agreed to match the District monetary investment in the program. Out of 105 applicants, 41 were selected, and 29 are still in it. The program started last summer with the trainees taking university classes, followed by a 3-week workshop offered by the District's mathematics specialists. The teachers were paid for the 3-week workshop. Their university tuition was also paid, so their major expenses were for books and parking. During this school year, the trainees are continuing in a university course and a practicum each semester. Next summer, they will complete the training with a 9-unit university segment. During the year, the District has provided a full-time resource teacher who visits and supervises the work of the trainees in their junior high school mathematics classes and provides individual and group inservice training. The decline from 41 to 29 can be attributed in large measure to the difficulty of the mathematics courses required by the university. The university soon recognized that the trainees needed to start at a lower level and then adjusted their course work accordingly. The District workshop included lesson planning, learning theory, and classroom management techniques. The program is considered to be a success.

Investment in People

Late last year, the legislature funded and approved the "Investment in People" program. Administered through Los Angeles County Schools, the program has several facets:

- local schools may write proposals for funds for development of their staff in mathematics, science or computer literacy;
- the training of the 29 teachers who are in the LAUSD/UCLA-sponsored mathematics training program will be continued; and
- universities and colleges may write proposals to help train emergency credentialees in mathematics and science (both USC and California State University at Los Angeles plan to submit proposals).

Partnerships with Industry, Government, and the Military

To resolve the growing shortfall of mathematicians, engineers, and scientists needed by industry, government, and the military, from time to time various partnership programs have been proposed. Last fall our Superintendent, working with the President of Cal State Dominguez Hills, proposed a plan for mathematicians and scientists in industry to donate several hours a week to instruct high school pupils. For many reasons, this "Pilot Program" has not yet started.

In recent weeks, the District has been contacted by the Partnership for Development of National Engineering Resources Project, a group from industry and the military. The group is interested in increasing support of university and secondary school science and engineering facilities and in providing additional incentives to attract science and mathematics teachers at the high school and junior high school levels. Through an ad hoc committee, representatives are presently exploring a number of possible action items:

1. To sponsor and support legislation which would allow for incentive payment to shortage-field teachers hired in the State of California.
2. To review national legislation directed at improving instruction in science and mathematics, with the intent to support and lobby for its passage.

3. To consider the funding of science or mathematics chairs at local high schools which would provide extra teachers in those fields, reduce class size, increase teacher prestige, and offer outstanding instruction.

4. To provide one or two periods a day instruction from engineers and mathematicians assigned from the military and industrial sector.

5. To provide engineers or mathematicians from industry to act as professional experts, releasing a classroom teacher who then could visit industry or observe other outstanding teaching.

6. To provide enrichment instruction by engineers and mathematicians from industry and the military.

7. To provide funds from industry for the purpose of retraining mathematics teachers of and for the District.

8. To provide equipment or funds for equipment to upgrade the mathematics and science departments in junior and senior high schools.

9. To study the possibility of granting sabbatical leaves from industry and the military to engineering and mathematics staff members to teach in the public schools for a year. The half salary from the industrial complex plus the regular salary paid by the District would be enough to compensate those specialists at their normal rate.

10. To provide sabbatical-type leaves for teachers to work in industry and therefore become upgraded in the fields of engineering, mathematics, and science.

The group plans to develop a 5-minute video presentation to use to solicit funds from large industries.

Fellowships

Another group of representatives from business is presently conferring with the District about the possibility of offering 50 summer fellowships to mathematics and science teachers to upgrade their skills.

MESA

The Mathematics, Engineering, Science Achievement Project (MESA), active in 30 California school districts, has as its purpose helping minority students go to colleges and universities to become engineers, mathematicians, and scientists. It has chapters in several Los Angeles Unified School

District high schools. Representatives from business and industry work with minority students who want to go to college to insure that they succeed by providing tutoring, field trips, study sessions, and generally providing a high level of support to the schools. The group raises funds from industry and receives a matching grant from the State legislature.

## Task Force

Another proposal is the formation of a task force under the leadership of the State Department of Education which would include representatives of business, industry, government, the military, and the schools to explore ways of solving the shortage of mathematics and science teachers and to keep up to date those presently teaching mathematics and science.

## Anyone Can Teach: A Myth

Experiences have shown that the fact that a person is knowledgeable in his subject field does not necessarily mean that he can teach others. There are few "born" teachers; yet most people can be trained to become adequate, if not outstanding, instructors. The skills, strategies, methods, and techniques can all be learned, but they cannot be learned overnight, in a week, or in one crash course. The semester of student teaching under the supervision of a master teacher is still an important part of learning to teach. During this training period, the student teacher has an opportunity to try out strategies, to apply learning theory, and to conduct daily discussion and evaluation of each planned lesson with the training teacher.

## E.T. - Educational Techniques that are "Out of this World"

When mathematicians and scientists and others want to become teachers, they must receive training in learning theory, learning styles, classroom management techniques, and in implementation of the teacher-directed lesson. Many universities and colleges offer very little in the way of methodology. It becomes necessary for the school district to provide inservice education. The District provides extensive staff development programs for teachers aimed at improving their skills and making them more successful in the classroom.

## Science and "Mathemagicians"

A good teacher candidate is a bright, knowledgeable (in his subject area), alert, sensitive, patient, enthusiastic person with genuine interest in young people. With these qualities, such a person can learn and become a top science teacher or "mathemagician."

## Long Range Considerations

While this paper has dealt with some programs in place, and some immediate plans for the near future, it must be emphasized that the problem requires long range solutions that will attract the very best mathematics and science majors to the teaching profession. In order to do that we must:

- reemphasize that teaching is a profession;

- seek public support for reimbursement for teachers equal to that of other professions;

- seek legislation which allows the school district to be competitive in salaries for shortage-field teachers;

- constantly remind college students that teaching is one of the most exciting and personally and psychologically rewarding professions there is; and

- instill a renewed self respect in the teacher, which comes from a feeling of security on the job, adequate salary, and professional recognition for a job well done.

Schools of the Future

If long range solutions do not come about, the Nation may be forced to implement, before the end of this decade, the school of the future. In that school, great and important concepts, knowledge and understandings will be presented by master teachers on videotape. Students will internalize these concepts by interacting with their own personal talking computers. Small group instruction will be conducted by less fully trained laboratory assistants. Other computers will provide drills to learn and master essential skills. Mastery of essential skills will be a prerequisite for advancement to higher levels of learning. The progress of each student will be carefully monitored and recorded by computers, and it will be the function of administrators and counselors to guide each student through an individually tailored program aimed at insuring that each student reaches his highest potential.

# PRIS$^2$M - A PROGRAM FOR STUDENTS BUILT UPON PROFESSIONAL GROWTH EXPERIENCES FOR TEACHERS

Douglas Seager, Curriculum Coordinator,
Rochester (New York) City Schools and
Industrial Management Council

In 1981 the National Science Teachers Association surveyed high school principals from across the Nation in an effort to ascertain the percent of newly employed science teachers who were unqualified. Here's what they found. In nine census regions, the lowest percentage they found was 9 percent, the highest 84 percent, and the average was 50.2 percent. When compared region by region with the pervious year, three regions were down, at most 3 percent, while five had increased, one of them by 17 percent. But these statistics only indicate a problem with newly employed science teachers. Let us look at teacher shortages nationwide by State. In 1980-81 there were 43 States showing a shortage of physics teachers, 35 were short mathematics teachers and 35 were short chemistry teachers. In 1981-82 even more States reported shortages of mathematics and chemistry teachers, although one less State reported a shortage of physics teachers.

In one well-to-do suburb of Rochester, N.Y., it took over a year to fill one physics opening. Just last week two of three candidates for a permanent substitute position in junior high science were unsatisfactory, and the third has changed her mind about teaching--preferring to be dropped from the substitute list.

The Program for Rochester to Interest Students in Science and Mathematics (PRIS$^2$M) was established in 1978, not to respond to the problem of teacher shortages, but rather to help increase the number of minority students eligible to enter engineering and other high level science programs. A relatively small effort, PRIS$^2$M has nonetheless found itself closely associated with many concerns regarding science education. In retrospect it may be that PRIS$^2$M's appearance was inevitable. The crisis now surfacing had its origins several years ago. A few of PRIS$^2$M's responses seem to be working in Rochester and may prove to be worthy of consideration on a significantly broader scale.

But first, let me present a brief overview of PRIS$^2$M itself. In 1977 Willis Sprattling, a senior official with the Xerox Corporation and member of the National Advisory Committee for Minorities in Engineering (NACME), challenged the Board of Directors of the Industrial Management Council (IMC) of Rochester, N.Y., to study the problem of minority parity in engineering. Soon after, the IMC established a task force to evaluate the challenge locally and, if appropriate, to establish an implementation plan. PRIS$^2$M is the result of this extensive evaluation effort.

Located in a high technology center (Rochester), the City School District has realized a very low number of minority students electing to take science courses, even fewer majoring in science and mathematics. In two predominantly minority high schools, we found a total of five students taking physics in 1978. Consider the following: approximately 40 percent of the Rochester work force is employed in industry, a total of 140,000 people. Most of our companies are based on technological products and services; there is almost no heavy industry here. As a consequence, technical and engineering skills are in great demand. Because so few minorities ever consider engineering as a career, opportunities for this segment of our population to acquire positions leading to professional and managerial rank are limited. Concerns on the part of both education and industry have resulted in a joint venture to increase the number of minorities majoring in science and mathematics so that more students will eventually be available to the increasing technically oriented work force in Rochester. In the long run, our goals are in keeping with those of NACME—enrollment in engineering and other technical programs by 18 percent of Rochester's minority student population. Nearly all of $PRIS^2M$'s programs take place within the City School District, with the full support of the Board of Education and Superintendent of Schools. In fact, one-third of the Board of Directors of $PRIS^2M$ is made up of school district personnel. One-third represents the Rochester community, and one-third comes from industry. This group encompasses considerable resources and helps provide many of the people, materials, and "in-kind" contributions which play such a significant role in the total program.

A 10-year funding commitment was made in 1978 which will total approximately $2 million in direct contributions for operating expenses and program activities. Numerous and varied in-kind contributions make the total financial commitment well in excess of that amount. Entirely funded by some 26 local industries, $PRIS^2M$ receives an average of $200,000 per year, nearly half of which supports projects directly impacting on students. Two full-time staff members carry out the program activities. One curriculum coordinator with extensive curriculum development and teacher training experience works hand-in-hand with the science/mathematics department and staff of the Rochester City School District. Primarily responsible for initiating and implementing academic programs, curriculum, and summer activities, the curriculum coordinator also links the school system with many resources from local industry. The community relations coordinator enjoys a high degree of acceptance from the minority community and bridges the community, education, and industrial resources while promoting the goals of the program to leaders of these organizations. An executive director from the Industrial Management Council oversees these linkages and promotes program support at the highest levels of industry, education, and the community.

Interventions

Dwindling interest in science during the crucial ages from eight to thirteen years prompted our first level of City School District program support. If students do not like science during the middle/junior high years, they are not likely to select science courses at the high school level. Our response to this dilemma was to initiate a supplemental curriculum project designed to provide a motivational alternative to the existing curriculum. We looked at the problem this way. Envision a funnel, widest at the sixth grade entry level end, but considerably narrower at the midpoint constriction where ninth graders enter high school. The spout represents the narrowest part—

consistent with high school enrollment in science. In terms of student interest, we want to expand the entire funnel and considerably widen the spout. As that happens the number of minority students electing additional science/mathematics courses will increase.

Supplemental PRIS²M activities for selected minority high school students entering the spout of this funnel must be motivational; they must occur frequently and consistently, and they must be appropriate. To these ends PRIS²M teams have been established at every grade level within each of the city high schools. Here the PRIS²M interventions are certainly noteworthy.

Students selected for membership must be enrolled in Regents-level courses in both science and mathematics. Further, they must maintain passing grades and continue to enroll in the Regents-level courses. Ninth graders would necessarily then follow a 4-year sequence in both disciplines. Required team activities include one monthly visit to a preplanned industrial presentation which emphasizes the importance of at least one fundamental science principle upon which that industry's product(s) or service(s) are based. (See Appendix A which lists industrial presentations.) Conducted during school hours, but located at an industrial site, the presentations are seen as a function of the student's school program, although initiated, developed, and funded by PRIS²M.

One additional required team meeting each month provides opportunities for a variety of activities including science fair project development, career awareness seminars, financial aid programs for seniors, and special seminars/programs on science/mathematics current issues. Held after school hours, these meetings are conducted jointly by a team "Coach" from the school building and several team "PROS," or role models from one or more of the local industries supporting PRIS²M. Social events, fund raising activities, and a team comradery develop a sense of belonging as well as interpersonal support systems between team members. For minority students, heretofore noticeably affected by a negative peer pressure towards science and mathematics, the team concept has played a significant role in reversing this peer pressure, now making it positive.

Additionally, three special summer programs for PRIS²M team members round out these unique interventions for our students. A 3-week Science/Mathematics Summer Workshop emphasizes direct learning "hands-on" experience for 100 ninth graders. Following the tenth grade a 1-week biology-based camp experience continues the sequence of special programs. After the eleventh year, a 9-week "Orientation to Engineering" program includes 1 full week at a local university followed by 8 weeks of internship training for which students are reimbursed by the industry in which they work. Under direct professional supervision, these students work in the laboratory, computer center, engineering facility, or other technical operation. The PRIS²M program enjoys considerable status and is credited with changing noticeably the attitude and work ethic of many of our students. They simply seem to be different students as entering seniors than they were as departing juniors only 2 months earlier.

Teacher Involvement

Teacher "burn out" is often blamed for conditions which interfere with the delivery of good science education. This includes a wide spectrum of concerns such as "too much to teach," "the kids are not interested," "the school does not support science," "too many nonteaching duties," "no variety in my teaching," "no consistency in my teaching assignment," and "parents do not support science." I believe "burn out" indicates a lack of satisfaction and incentive for the job of teaching science. Many of the above concerns can be blamed for this and certainly add to the "drudgery" of teaching science as perceived by many science teachers. The status of science education has been lowered to second class throughout the school curriculum, and the role of science in our society generally has resulted in a populace which is largely scientifically illiterate.

Teachers are migrating out of the profession with good reason. Some enter industry for better paying jobs, others change careers to escape bells, cafeteria duty, and dwindling student interest. But still I attribute many of the losses to the lack of professional satisfaction and incentive. To quote Tom Lamme in a recent (December 1982) letter to the American Federation of Teachers (AFT), "Many qualified teachers are dissatisfied with more than their economic status. Once they have mastered the challenging emotional demands of teaching, many discover that the intellectual challenge is inadequate. They are bored....Too many teachers can only watch as the exciting sweep of technological progress passes them by. They may try to keep up as hobbyists or readers, but there is little opportunity for them to become involved firsthand. School districts are content that classes are 'covered' and provide lttle incentive for coursework beyond a certain level. Teachers who pursue their interests in technology at their own expense often find themselves in demand by industry. The next surge of industrial expansion will take more of these teachers out of the classroom and open more attractive options for those qualified graduates who are needed as new teachers."

Can anything be done about this? PRIS$^2$M's long term objectives include the development of positive attitudes and renewed enthusiasm on the part of science teachers for the career of teaching science. Efforts in this direction are multifaceted and provide teachers with a variety of professional experiences for which they are employed during out of school hours and summer vacation.

New Curriculum Development

To date the most significant of the professional opportunities has been the formulation and development of an entirely new junior high school/middle school science curriculum for the Rochester City School District. This effort alone has directly involved 50 teachers over the past 5 years and has resulted in an unique process skills curriculum which incorporates several very special roles for the science teacher. In fact, as in any curriculum development project, the commitment of the principal contributors extends well beyond the initial involvement and often results in increased motivation, renewed enthusiasm, and increased self-esteem. This aspect of PRIS$^2$M represents one of our major responses to the problem of "Teacher Shortage in Science and Mathematics."

Although the entire process is important to the development of a new curriculum, I will discuss here only the salient features pertaining to teacher motivation and incentive. First, each selected science and mathematics teacher becomes the principal author of one completely new science unit. All of the principal authors also develop at least one module (activity) for each of their counterparts' units. Social studies writers develop modules for each principal author's unit, while an English/reading specialist oversees the grammar, reading level, and appropriate student jargon. A graphics specialist works with all writers, and a grade level project coordinator supervises the entire process. Checks and balances throughout have helped to ensure that the overall unit objectives are indeed satisfied by the content developed for each unit. The resulting science units soon appear in pilot classrooms where they undergo intense scrutiny.

Pilot testing is, of course, carried out by science teachers, in many cases different teachers than those who authored the material. This level of involvement requires inservice training sessions (conducted by the unit author) and critical feedback sessions which enhance the final curriculum format and content. Pilot testing is considered nearly as important as the author/teacher involvement and expands the scope of this project in terms of the total number of professionals.

Summer School Staff

Teachers work hand-in-hand with professional minority role models to deliver the three summer programs referred to earlier. Our 3-week long Science/Mathematics Summer Workshop is managed by one mathematics teacher, who essentially fills the role of principal for this program. The teaching staff consists of six additional teachers who have found their summer experience so rewarding that they begin calling in to inquire about preparations and plans as early as February. By the way, some of the summer workshop activities have found their way into these teachers' regular classrooms, and a few activities are now built into the overall curriculum project mentioned earlier.

Additionally, two teachers conduct a special science camp for post-tenth grade students, and two others teach during the 1-week "Orientation to Engineering" for post-eleventh graders.

Even more unusual perhaps are some of the specific components of the PRIS$^2$M curriculum. Let me discuss how some of these components tend to blend many of our concerns regarding the status of science teaching into a functional model--at least on a small scale.

Unique Features of the Curriculum

The curriculum development process represents a unique kind of teacher inservice training for the writing staff. Our process combines research on science teaching from the National Science Teachers Association (NSTA), studies regarding the early adolescent from the National Science Foundation (NSF), trends in science education from the National Assessment of Educational Progress (NAEP), current literature on science activities, and process skills appropriate to the junior high school student. Further, consultants have impacted on the thinking of authors/teachers as they help to formulate goals and techniques designed to deliver science to students in a motivational way, while incorporating meaningful science skills and experiences.

Once the curriculum materials have been prepared, the writing staff become the teacher trainers for a cadre of pilot teachers. In this way the current research findings as well as the new activities and approach to teaching science are enthusiastically conveyed to a larger audience. Remember, too, that the writers and pilot teachers work together in the school district providing immediate feedback and support when questions arise. This involvement with writing and teacher-training seems to enhance their commitment to the science teaching profession, to say nothing of their increased enthusiasm for teaching a unit which they authored!

The Curriculum Format

Also unique to this curriculum is a degree of flexibility which allows the teacher some choice of units to be taught. Required units will ensure that basic process skills are covered. Choice units may be drawn from a repertoire of other PRIS$^2$M units, or even a strong "content" based or "textbook" unit of the teacher's choice may be included. As students in junior high school need to learn to make decisions, so are teachers asked to do the same. If, for example, a teacher perceives the need for his/her class to study certain content areas, then the opportunity exists during the choice units to do so. Still the overall emphasis on development of process skills will not be diminished. Some teachers, less willing to forego their traditional curriculum, have accepted our new approach because it doesn't limit them from teaching a favorite unit or chapter from their own repertoire.

The Teacher Module

Most significant of all the unique features perhaps is the development and incorporation of the Teacher Module as a part of the new curriculum. Simply stated, each science teacher is required to carry out some form of ongoing science exploration and to continuously share both the process and the results with students. The importance of this type of role modeling should not be minimized.

When students perceive their teachers to be actively involved in their chosen field personally as well as professionally, the development of a role model image begins to form. This image may very well enhance the status of science in the eyes of our young people, since their teacher is seen not only to be a teacher of science, but one who finds the tenets of the profession worthy of being incorporated into private life.

Many teachers exhibit their particular field of expertise beyond the classroom. Music teachers are likely to be involved in the performing arts by playing in a concert orchestra, a local band, or by teaching youngsters music through private lessons. Physical education instructors often are involved in sports and physical training outside the school day. To a somewhat lesser extent, teachers of other specialized subjects continue to pursue various facets of their training through personal time activities, such as the English teacher who writes poetry, the history teacher who serves as a Community Historian or the industrial arts teacher who designs and builds furniture as a personal business.

The "Teacher Module" is the vehicle which allows the science teacher to role model the scientist. It formally establishes a place in the curriculum for the teacher to select a problem, activity, study, or science-related hobby to pursue and share with the class on an ongoing basis.

To encourage this, PRIS²M has initiated several incentives for science teachers. First, the Rochester Council of Scientific Societies (RCSS) has enthusiastically begun a series of meetings between active industry-based research scientists and city school science teachers. Major outcomes of the first of these meetings include a review of research principles used by active scientists and a discussion based on some of the current research in progress right here in Rochester. Also, because RCSS provides many of the local science fair judges, considerable discussion centered around the attributes of a good science project, including heavy emphasis on process, diligence, interpretation of data, and formulation of new problems. The second incentive, offered by the City School District (CSD), is a small grant for special equipment or materials needed by the teacher for his/her research project. An unstated incentive resulting from direct contact between scientists and teacher is the development of personal contacts which will enhance the delivery of science to our students.

One anticipated long term outcome of this relationship between science teachers and scientists is the eventual utilization of teachers by area scientists for carrying out some level of supplemental research in the science classroom. Beyond this, we anticipate some degree of significant summer employment for selected science teacher researchers.

## Program Results

Of the fifty curriculum developers involved with PRIS²M, two are currently enrolled in Ph.D. programs, concentrating in the field of educational evaluation, one editor now edits the Science Teachers Association of New York State monthly newsletter, two are currently editors/supervisors for final editions, and the rest are still teaching. There have been no losses to new careers! By way of contrast, during the same 5-year period, 18 other CSD classroom science teachers have left the classroom altogether.

Over the past four years, 169 students have participated in our Orientation to Engineering program. One hundred eighteen are now high school graduates, 66 are currently enrolled in college, and 33 are now in engineering schools.

## Recommendations

1. Develop a process for upgrading the status of junior high/middle school science eudcation, including a process for identifying and selecting science teachers committed to working with the early adolescent.

2. Support the development of junior high/middle school science curriculums which are based on:

   a. development of basic process skills and integrated process skills;

   b. providing students with some choice of topics within the curriculum; and

   c. requiring some form of student long term study or project as a component of the curriculum.

3. Encourage and support the participation of science teachers in the development of curriculums, curriculum revision, inservice training, pilot projects, and ongoing revision and evaluation of local science programs.

# APPENDIX A

## INDUSTRY PRESENTATIONS

| INDUSTRY | TOPIC |
|---|---|
| Bausch and Lomb | Optics |
| Case-Hoyt | Color Reproduction |
| DuPont | X-Ray Technology |
| General Railway Signal | Electromagnetism |
| Gleason Works | Motion Transfer |
| Kodak Apparatus Division | Microprocessors |
| Kodak Park Division | Chemistry of Silver |
| Ragu' Foods | Microbiology |
| R. F. Communications | Sound Waves |
| Rochester Gas and Electric | Power Generation |
| Rochester Products | Air Pressure |
| SYBRON/Nalge | Latent Heat |
| SYBRON/Taylor | Electronics |
| Xerox | Computer Aided Design |

TEACHER SHORTAGE IN SCIENCE AND MATHEMATICS:
WHAT IS HOUSTON DOING ABOUT IT?

Patricia M. Shell, Superintendent for Instruction
Houston Independent School District

There were days during the 1978-79 school year when as many as 6,000 secondary students in the Houston Independent School District sat in mathematics or science classes without a certified teacher. On September 1, 1978, there were 47 secondary science and mathematics teacher vacancies in the district. On September 1, 1982, there were two mathematics teacher vacancies and one science teacher vacancy. This dramatic change resulted from specific actions the district, the Nation's sixth largest, has taken to address one of education's most critical problems.

It is important to have an understanding of the circumstances which were the impetus for the district's actions. In the second half of the 1970's, the Houston Independent School District was facing many of the problems common to urban school districts across this Nation. Approximately one-third of all public school children are in urban districts which are responsible for educating a mobile population, with large numbers of children who are economically and educationally disadvantaged, bilingual, or from one-parent families or families in which both parents are employed.

The Houston Independent School District provides an example. Approximately 195,000 children, or one-tenth of all children enrolled in public schools in Texas, are enrolled in the Houston Independent School District this current school year. The student body is 43 percent black, 32 percent Hispanic, and 22 percent white, with a growing number of children who are Asian/Pacific Islanders. Approximately 6,000 pupils are children of undocumented workers. This year 29,000 children have been identified through testing as having Limited English Proficiency (LEP). While the majority of those have Spanish as the other language, 96 discrete dialects have been identified. Compensatory education programs serve over 50,000 children, and approximately 100,000 are eligible for either free or reduced cost lunches.

There are 20,000 handicapped children in programs of special education. Of all pupils, 70 percent have neither parent at home during the day and 38 percent come from single-parent homes. The mobility rate for the district as a whole is 39 percent, and some inner-city elementary schools have a 99 percent mobility rate. A major school-operated transportation system carries students to the 240 campuses scattered throughout the 311 square miles that comprise the district. An operating budget of approximately $500 million is approved for the current school year.

To all of these complex factors, add the problems of sheer size, the difficulties of moving about in a large city without an adequate mass transportation system, the media's continuing portrayal of urban schools as places of violence, and the discrepancy between teachers' salaries and salaries offered by business and industry in a metropolitan center dominated by finance and the petrochemical industry. These are the factors which contributed to the increasing difficulty the Houston Independent School Disrict was having in 1978-79 in filling science and mathematics teaching positions, especially in the inner-city schools where high staff turnover was common.

THE PROBLEM

On September 1, 1978, there were 34 secondary mathematics teacher vacancies and 13 secondary science teacher vacancies in the Houston Independent School District. With each teacher scheduled to teach five classes a day, this meant that a total of 235 classes of mathematics and science, each with an average of 25 students for a total of at least 5,875 students, did not have a certified instructor. Investigation has shown that there are probably large numbers of students who graduated from certain large high schools having received nearly all of their secondary science or mathematics instruction from substitute teachers.

Not surprisingly, there was in this same time period increasing evidence that while achievement test scores of the Houston Independent School District elementary level students continued to climb, secondary students were not achieving at expected levels. The district was also experiencing a shortage of teachers in special education and bilingual education. There was, moreover, evidence that some teachers currently employed did not themselves possess a level of skill sufficient for their teaching assignments. During this and the next school year, it became clear to the top administration that the teacher crisis--the shortage of qualified teachers in critical fields such as science, mathematics, and bilingual education--had become the single, most critical issue facing the district. That perception was clearly stated in a report to the Board of Education:

> What is the teacher crisis? The teacher crisis is a dramatic shortage of teachers in critical fields such as mathematics, science, and special education. It is high teacher turnover in urban schools resulting in detrimental instability in urban classrooms. It is placing before our students, teachers who themselves cannot read, write, and compute in an acceptable manner. It is high absenteeism and low morale. It is a complex conglomeration of factors which has resulted in widespread wavering from traditional standards of excellence. At a time in the history of civilization when the demand for learning is greater than ever before, the ability of the public schools to perform the task has been seriously jeopardized.

HOUSTON INDEPENDENT SCHOOL DISTRICT'S RESPONSE TO THE PROBLEM

The district's responses to the problem, an incentive pay plan and a school-based retraining program, have been a dramatic departure from solutions traditionally espoused in public education. But the approach to introducing these plans followed the pattern set during the last 9 years by the General Superintendent, Dr. Billy R. Reagan. That approach is to communicate the scope of the problem in every way possible to all segments of the community--school staff, parents, business community. Staff vacancy reports and student test scores were made public in every available forum.

Widespread community support was expressed when the Board of Education adopted the Second Mile Plan, an incentive pay plan for teachers, effective in September of 1979. The plan, an expression of determination to attack the teacher crisis aggressively, was hammered out without benefit of precedent or example, for while the concept of incentive pay for teachers has long been debated in education circles, it has never been comprehensively worked out and implemented until now. As of September 1982, Houston remains the only major urban school system to implement such a plan.

The Second Mile Plan targets four specific areas:

- improvement of instruction;
- shortage of teachers;
- staff stabilization; and
- recognition of teaching as a rewarding career.

The purpose of the plan is to reward those teachers who go beyond the minimum required to meet the instructional needs of their students, teachers who go "The Second Mile." The plan provides financial incentives over and above their normal salary to teachers who teach in curriculum areas or campus locations where critical shortages exist.

Teachers must meet certain minimum requirements to establish eligibility for stipends and then must apply for each stipend. To be eligible, an employee must:

- hold an appropriate valid teaching certificate or permit;
- be assigned to a school or instructional site;
- be paid on a teacher salary scale;
- have an acceptable performance evaluation;
- have limited absences (there is currently a plan which allows absences to be averaged over a 3-year period, with a 3-year total not to exceed 15 days, or 5 days per year); and
- be a fulltime teacher, nurse, or librarian.

An employee may qualify for a bonus stipend in each of six categories, which are obviously consistent with the four main target areas the plan was designed to address:

- <u>Contributing to Outstanding Educational Progress by Students</u>

  Previous academic achievement and a number of other factors are used to predict the expected test score averages for each school campus. If the school's average score exceeds the predicted score, each eligible teacher receives an $800 stipend. This component is especially attractive to the business community which is accustomed to rewarding demonstrated productivity.

- <u>Teaching in an Area of Critical Staff Shortage</u>

  Each year the personnel office determines the instructional areas which have critical staff shortage, with preference given to areas under Federal mandate or required for graduation. Since the inception of the program 4 years ago, stipends have been given to teachers of science and mathematics, bilingual and special education. Currently, high school mathematics and science teachers are eligible for $800 stipends. Stipends for special education teachers range from $600 to $900. Bilingual teachers may earn an extra $1,000. It is anticipated that these stipends will be raised within the current year.

- <u>Teaching in a High Priority Location</u>

  Teachers who remain in schools with high concentrations of educationally disadvantaged students are eligible for a $2,000 stipend.

- <u>Maintaining Outstanding Teacher Attendance</u>

  While an attendance factor is included in the eligibility requirements, special stipends may be paid to teachers who exceed these baseline requirements or are absent 5 or fewer days during the year. The teacher must work in the district the following year to receive the stipend.

- <u>Participating in Professional Growth Activities</u>

  Teachers completing college courses in curriculum areas related to their teaching assignments or in areas of teacher shortage are eligible for stipends. Those who voluntarily attend district approved inservice may also apply for professional growth stipends. For each 6-hour block of college coursework or each 72 hours of approved inservice, the stipend is $300.

- <u>Unique Campus Assignment</u>

  Teachers who teach at a campus for which no test data are available either because the students are not at the school long enough to be tested or because the students are not able to be tested using standardized tests, may receive the unique campus assignment stipend. Teachers receive stipends ranging from $450 to $750. These teachers are not eligible for the outstanding educational progress stipend.

Predictably, reactions to the Second Mile Plan have been varied. As noted, the business community has supported both the concept and the expenditure of several million dollars each year to implement the incentive pay plan. The three teacher organizations representing Houston teachers have opposed the plan, arguing that funds spent for the plan should be used to provide across-the-board raises or fringe benefits for all teachers. But more than half of the district's teachers responded to a research department survey that the plan should be continued. Those who received stipends rated the plan more favorably than those who did not.

After 3 years of operation, many positive results of the plan are evident. In the four critical areas for which stipends are paid, total beginning of the year vacancies decreased from 195 in 1979 to 30 in 1982. During the years from 1978-79 to 1981-82, total district teacher turnover for all reasons was reduced by 6.8 percent. Absences of teachers in the critical staff areas were reduced from an average of 10.3 days a year in 1978-79 to 7.1 days in 1980-81. Over $17 million in stipends has been paid to teachers during this 3-year period, with many eligible teachers augmenting their salaries by more than $3,000 per year. Title I funds are used for the high priority location stipends; all other stipends are paid from local funds.

The district continues to monitor the results of the Second Mile Plan and to modify the plan to meet changing local needs. There is ample evidence that financial rewards to teachers through a carefully administered incentive pay plan can help meet one of education's major crises.

During the 1981-82 school year, the Houston Independent School District implemented another program--Project Search--which directly targeted the shortage of mathematics and science teachers. Project Search is a local school district staff retraining program, operated in conjunction with local universities, which identifies and recruits already employed teachers into training programs leading to certification in mathematics and science. Elementary level teachers with some college credits in mathematics or science and an interest in teaching one of these subjects at the middle/junior high school level were put into an intensive tuition-paid program this past summer. Likewise, middle/junior high school teachers were recruited for training programs leading to certification for high school science or mathematics.

The district not only paid for college tuition and books, but paid these teachers a $250 per course stipend as well. The $250 stipend was contingent upon an A or B grade. Teachers in the program signed agreements to remain in the district for 3 years in mathematics or science positions or else to repay the district the cost of their training.

Over 300 teachers came to an orientation meeting designed to recruit 50 teachers for retraining as mathematics teachers. Careful screening for good academic records, good evaluations, and good recommendations from principals followed.

At the end of the first training cycle this summer, 34 teachers were placed in new assignments as mathematics or science teachers. In spite of careful screening, some applicants could not maintain the required all A and B grades and were counseled out of the program. Two participants have moved from the district.

A total of $68,511 has been expended in this program to date.

SUMMATION

These are the major actions taken by the Houston Independent School District to address the shortage of mathematics and science teachers. A determination to address the whole issue of the image of the teaching profession, the number and quality of students being recruited into the profession, and the quality of the teaching-learning process permeates the district and is expressed in many ways. Standards for promotion and graduation are being raised; a comprehensive staff assessment and assistance program is underway; technology is being used to support the instructional process and plans are proceeding for the opening of two magnet high schools.

The Houston Independent School District will continue to take whatever actions are necessary to assure that its students have qualified teachers in all subject areas.

DISCUSSION OF
SCHOOL SYSTEM RESPONSE TO THE PROBLEM OF
TEACHER SHORTAGE IN SCIENCE AND MATHEMATICS

Charles Thomas, Superintendent of Schools,
North Chicago Public School District No. 64

As a practicing superintendent for the last 10 years, I am interested in efforts undertaken to solve the problems of the shortage of mathematics and science teachers. The presentations we have heard attest to the variety of concerns and the kinds of activities that are being tried.

The Los Angeles story, in my opinion, is an eclectic approach to the problem of the shortage of teachers. I applaud the wide range of activities and considerations that are involved in the Los Angeles program. I did not have any major concerns with it. I think that the activities to upgrade, retrain, and credential teachers are extremely important as we deal with the shortage.

I do not feel that the school system had time to consider some of the theoretical concerns of the various activities. This is understandable because the requirement for school systems is not deliberation on theoretical underpinnings of the program approach but immediate movement, action, and responses to educational problems--such as the teacher shortage.

One important thing Los Angeles is doing similiar to my school system, is involving the military as well as industry in their endeavor. North Chicago is unique in that 50 percent of our students are connected to the Great Lakes Naval Training Station. Further, we involve Abbott Laboratories, one of our largest taxpayers. They have donated microcomputers to our school district.

I applaud the PRIS$^2$M program for taking the initiative to increase the number of minority students capable of entering schools of engineering. While some may say focusing in on minority students might be narrow, I think the curriculum development outcomes and the other activities improve the mathematics and science curriculum and have systemic values. So in the long run you are improving your educational system at the same time you are creating a climate for success amongst minorities.

One of the program's dangers, I would say, could be the development of elitism among the participating students. But on the other hand, if you are getting increased student interest in participation, if you are increasing the numbers, which is your objective, then certainly in this case elitism is not bad.

I like the idea of the teacher module. Many times when we recruit teachers, if I am recruiting an art teacher, I will ask, "Are you an artist or an art teacher?" This is a very difficult question for many applicants to answer. Usually they come back with some kind of response which will come down the middle, to indicate that they do have the talent to perform but that they are interested in teaching and their commitment is to teaching.

I think there is no better way to stimulate young people than to have science teachers, some part of the time, acting as scientists and demonstrating that capability. So I like the idea of a "scientist in residence" type of model which Douglas Seager talked about. The program in Rochester exemplifies the kind of things many school districts are talking about when they talk about cooperation with industry.

Patricia Shell, in Houston you need not apologize for having the money. If you have the money, spend it. You had a teacher problem. You responded to the problem. You had the monies for programs so I recommend that you should continue your programs as long as you're getting results.

Some may comment, "Well, what about the district's overall teacher force quality? Are you doing anything on that end of the spectrum?" I believe that you are concerned about the quality of all teachers. From what I know about Houston and Billy Reagan, your Superintendent, I'm sure you're attacking that particular problem, too.

One concern--it might be because I really don't know enough about the program--are you rewarding people beyond the minimum? What about the ordinary teachers? Does it promote in some way a kind of mediocrity? Another concern might be: How practical is it nationwide?

I know you are concerned about Houston, but I have a concern about the problem in general, as I'm sure you do, too, so the practicality of it might be a concern. Again, if you have the money and you are in a position to spend it, the outcomes--while we may cavil from a moralistic point of view--indicate that it works.

E.B. Howerton, Jr., Associate Superintendent for
Personnel and Administrative Field Services,
Department of Education, Commonwealth of Virginia

I'm going to take the liberty of jumping to the end of my remarks. Frankly, I think Dr. Thomas expressed it very well. We had an opportunity to confer just long enough to decide that we were in total agreement. There is absolutely no question whatsoever that the three plans presented are workable. They are plans which there should be no apologies for whatsoever. They are programs that we have had the opportunity in our own Commonwealth to review, to consider, to implement to a certain extent.

Very quickly, Virginia happens to be a State in which 38 percent of all of the school divisions indicated this past school year that they had extreme difficulty in securing mathematics and science teachers. As a matter of fact, 42 percent of the division superintendents responded that they were unable to secure credentialed persons in the area of physics. Among our public colleges and universities, which number 36 in Virginia, we had only nine graduates in the area of physics, and only two of those pursued a career in teaching. I don't think these statistics are unlike those which are found in many other States.

Let me share for a couple of minutes some of the cautions that I think can be extracted from the three projects, and these relate more to the level of affinity which I have than to any position of opposition.

One, I think the question of salary differentiation is one which should be looked upon very carefully. I am still concerned about the English teacher who spends many, many hours at home in the evening grading papers and happens to be next door to a mathematics or science teacher who would not necessarily have that same task yet would be compensated differently.

I think we have to be careful in making an assumption that to retrain anyone necessitates that they take everything that one would have taken just as if they were beginning their training from the outset. Corollary to that is the doubt that one can be retrained by simply picking up where they happen to have left off many, many years earlier. I don't think we have found, from the very limited studies which have been made of retraining efforts, that one retains all of that which one learned many years earlier.

The issue clearly is multiplied by two other factors, namely, that many States (37 States) are considering increasing the requirements for graduation from high school by one unit in mathematics, one in science. And the statistics were provided here today that that would increase the number of required sections of both mathematics and science by anywhere from 15 to 25 percent, depending on the State in which you happen to reside.

Pat, one aspect of your program that I had the opportunity to review is that of performance as a factor related to pay. I think performance is clearly a factor, but I would caution anyone against using performance as the single criterion, or actual classroom teaching performance as the single criterion, upon which an incentive would be afforded.

# SESSION VII
# PUBLIC AND PRIVATE SECTOR RESPONSE TO THE PROBLEM OF TEACHER SHORTAGE IN SCIENCE AND MATHEMATICS

## ARGONNE SUPPORTS PRECOLLEGE EDUCATION IN SCIENCE AND MATHEMATICS

Juanita R. Bronaugh, Director of Affirmative Action Program,
Argonne National Laboratory

Argonne National Laboratory was originally created to perform nuclear reactor-related research. In recent years the laboratory's efforts have expanded to embrace studies of many other energy technologies. The laboratory takes pride in the fact that over half of its employees, 1,800, are scientists and engineers who hold advanced degrees and many of whom hold joint appointments with the University of Chicago. Interaction between the laboratory and the university community has existed for a long time.

However, Argonne is faced with the fact that, like other research and development facilities, it must compete for well trained scientists and engineers in a highly competitive national labor market. Because emphasis on solving problems of decreasing industrial productivity, environmental stress, and shifts in the economy are bringing the demand for technical people to crisis proportions, innovative ways had to be found to increase opportunities and to effectively utilize highly trained manpower.

As a member of the research community that has traditionally looked for permanent employees from the pool of postdoctoral students, it was in Argonne's self-interest to help improve the quality of precollege education. Therefore, the laboratory's Division of Educational Programs has developed several formal precollege activities designed to bring about participation on the part of teachers and students in research programs.

Although there was acceptance of the fact that the Nation's science and mathematics education was in a pernicious state, the precollege thrust was not readily accepted at Argonne because of several widely held myths. Among the myths were: the goals of the laboratory and the public schools are not compatible; certain segments of the society are incapable of understanding the concepts and participating in the fields of science and engineering; and professional scientists and engineers would not be willing to associate with public school students and/or teachers.

You will note that as I outline Argonne's involvement in precollege programs that these myths have all been dispelled and that some of the strategies employed are modeled after other longstanding precollege programs like PRIS$^2$M in Rochester, New York and the Saturday Science Academy in Atlanta, Georgia.

The objectives of our programs are twofold: (1) to prepare a future generation of researchers; and (2) to increase the scientific literacy of the populace as a whole.

Presently, Argonne National Laboratory sponsors and participates in programs aimed at assisting precollege students. These programs are described below.

I. High School Summer Research Apprenticeship Program (HSSRAP)

The High School Summer Research Apprenticeship Program is designed to encourage minority and female sophomores to continue their high school studies in science and mathematics during their junior and senior years. The students participate in a 6-week program which offers exposure to a broad spectrum of energy-related research programs at Argonne and to Argonne's scientific and engineering staff. The program also enhances the students' educational experience by providing supplemental work in mathematics, science, and communication skills.

An applicant for the program must be in the upper 20 percent of his/her class and have completed 2 years of mathematics (through geometry), 1 year of biology, and 1 year of chemistry. Applications for participation are only accepted from those students attending schools in the Greater Chicago Area. Although all the students accepted in the program must have met the required criteria, there is a lack of uniformity in the kind of mathematics, biology, and chemistry courses the students have completed. Therefore, it is necessary to begin the program with structured classes to ensure that all participants begin with a common knowledge base.

During the 6-week program, emphasis is on small group research projects, instruction in computer science, elements of nuclear physics, crystallography, environmental chemistry, and scanning electron microscopy. Lectures and laboratory experiments are conducted by an Argonne scientist or engineer.

There are other programs aimed at increasing the number of minorities and females entering science and engineering in the Chicago area. But until the implementation of Argonne's sophomore program, there was no vehicle for talented tenth-grade students. Programs such as Early Identification and Inroads at Illinois Institute of Technology focus on identifying the academically talented student in the junior year of high school. Now students who participate in Argonne's summer program feed into the IIT Programs during their junior year of high school. After graduation, some of these students return to Argonne to participate in the Precollege Program in Science and Engineering (PRE-COOP).

II. Precollege Program in Science and Engineering (PRE-COOP)

This program was designed to provide college bound students an opportunity to work with professional scientists and engineers and to encourage the student to persevere in his/her studies in science, engineering, and mathematics at college. The competition for this program is very keen. Only one of four applicants is admitted to the program.

Emphasis in this program is on research. Each student becomes a part of an established Argonne research team and either pursues some aspect of the ongoing research independently, or assists with the efforts of the group. Each student is expected to prepare a written cogent summary of his/her research project.

III. Adopt-A-School

The laboratory also participates in the Chicago Public Schools' Adopt-A-School Program. This program was initiated by Ruth Love, Superintendent of the Chicago Public Schools, in an attempt to improve the Chicago schools with resources that are otherwise unavailable to the schools.

Through the program the laboratory provides technicians to repair equipment, scientists to give lectures and seminars, institutes for teachers, and tours of the research facilities.

One of the precollege programs Argonne is participating in was the direct result of an economic concern for the city of Chicago.

In 1981, Jane M. Byrne, the Mayor of Chicago, asked Walter E. Massey, Director of Argonne National Laboratory, to chair a Task Force on High Technology Development. The primary objective of the Task Force was to foster the development of new science-based business in the city and improve the local economy by providing new jobs and opportunities for its citizens. The Task Force analyzed precollege education in the Chicago area, and recommended that private industries and universities in the area work with the Board of Education to help improve the quality of science and mathematics at the precollege level. The Task Force report (1982) states:

> When considering the location of business in Chicago, it must be recognized that some areas of the city are perceived as unattractive with respect to quality of life, amenities, and services. One particular concern is the quality of precollege education offered in certain areas of the city. Good schools do exist and the quality of Chicago's schools appears comparable to those of other major urban areas; however, the perception of, along with the quality of public education, needs to be improved. It is recognized that this is a national problem as well as a regional one.

In response to the recommendations made by the Task Force, Mr. Richard Morrow, President of Standard Oil Company of Indiana, convened a meeting of representatives from high technological industries, universities, and research facilities in the Chicago area to discuss joint efforts with the Chicago Public School System that might demonstrate how the educational system in the Greater Chicago Area might be capable of producing the quantity and quality of skilled personnel required by new high-technology industries.

IV. Chicago Area Precollege Engineering Program (CAPCEP)

As a result of this meeting, the Chicago Area Precollege Engineering Program (CAPCEP) was established. CAPCEP is a partnership involving industries which employ engineers, scientists, and other technical personnel, public and private elementary and secondary schools, and colleges. CAPCEP's bylaws state the purpose of the partnership is "...to increase the number of minorities in science and engineering careers by providing technical, financial, and administrative assistance to Chicago area...school systems in order to enrich the academic curriculum and develop student interest in these careers."

The program concepts are to be initiated in three phases.

Phase I. CAPCEP activities in this phase focus on planning, initiation, and evaluation. Six Chicago public elementary schools which reflect the racial, economic, and social characteristics of the school system as a whole have been identified to participate in the pilot program. Elements of the pilot program consist of identification of needs, program development, inservice training, instructional assistance, and curriculum development.

Presently, the results of a questionnaire completed by 700 elementary school teachers are being tallied and analyzed. The information gathered from this needs assessment will be used to develop the inservice training and other program elements designated for Phase I.

Phase II. During this phase CAPCEP's activities will be expanded to include the high schools serving the feeder elementary schools participating in Phase I. A sequential program plan will be developed for the participating high schools. Additional elements such as a peer support system, tutoring, career information, and recognition activities will be included as an integral part in this phase of the program.

Phase III. The program will be expanded to include all remaining elementary and secondary high schools in the Chicago area during Phase III.

CAPCEP is unique. Unlike other existing precollege programs in the Chicago area, CAPCEP operates within the structure of the schools, with most of the program's activities occurring during regular school hours.

In addition to the precollege programs already mentioned, Argonne is exploring other efforts which will assist in increasing the pool of students pursuing science and engineering degrees. Many of these efforts are yet in the embryonic stage.

Two of these programs are: TSTM and Saturday Science Academy.

V. Tomorrows Scientists, Technicians, and Managers Program (TSTM)

We are presently reviewing a proposal for precollege involvement with the Aurora Public School System. The program, Tomorrows Scientists, Technicians, and Managers Program (TSTM), is specifically designed to increase the number of minorities entering the scientific, technical, and/or business labor market. Unlike CAPCEP, which takes a systemic approach and operates within the schools, TSTM will focus on selected minority students in grades 9 through 12 and conduct its activities outside the school structure.

VI. Saturday Science Academy

We at Argonne are excited about another program that will be implemented in May of this year. The Saturday Science Academy is modeled after the Science Academy implemented by the Atlanta Resource Center for Science and Engineering. Whereas Atlanta's program is an academic enrichment program for elementary and middle school students in grades 3 through 8, Argonne's program is designed to focus its efforts on highly talented students in the 4th grade.

We are attempting to plant the science/mathematics germ in kids at a very early age, hoping that with proper encouragement and development some of these students will become the scientists of tomorrow.

Our initial efforts will be a pilot program for 15 participants for a 6-week period. Because we are scientists and engineers--researchers, not educators--we sought and obtained the services of curriculum specialists from surrounding colleges and universities to assist us in this program. Staff scientists and engineers have submitted suggestions and volunteered to give lectures and/or demonstrations. A comprehensive evaluation is planned before the program is expanded.

These are programs that we are very excited about!

In our eagerness to respond to the numerous requests for assistance from the Chicago area schools, our approach to precollege science and mathematics education has been an eclectic one. We are now raising the questions: Is more better? Should we respond to all requests for assistance? Are the students deriving benefits from our programs? Are we utilizing our resources effectively?

The precollege activities are now being evaluated to determine the impact of the programs on students and Argonne personnel. Because we are determined to offer quality programs, we will undoubtedly narrow our focus, concentrating on those things that we believe we can do best. Whatever direction our precollege involvement takes us in the future, it will be one that demonstrates Argonne's continued commitment to precollege education in science and mathematics.

Walter E. Massey (1982), Director of Argonne, sets the stage for our commitment when he declares:

> It is in our self-interest as members of the research community to make sure that we replenish scientific and technical talent for future generations, and it is in our self-interest that the populace as a whole become scientifically and technically literate.

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## SCIENCE MUSEUMS AND SCIENCE EDUCATION

Bonnie Van Dorn, Executive Director,
Association of Science-Technology Centers

To complement science education in schools, science museums offer programs at the cutting edge of science education activities in the United States and the world. For example, there are mobile computer van programs, science camps, programs for handicapped youngsters, teacher inservice training, and the use of participatory exhibits. This paper describes many of the excellent programs offered by the approximately 100 museums in the United States belonging to the Association of Science-Technology Centers.

The variety of science museum programs is striking and addresses the needs of diverse audiences. The programs are designed for many age groups, ability groups, interest levels, and educational levels from preschool through higher education. The types of programs are equally diverse, ranging from the very informal exploration of exhibits in museums to formal classroom situations where graduate credit may be offered. A common characteristic of museum education programs is the involvement of other education agencies, private and public organizations, and the media. These collaborative efforts often have a long history preceding the current emphasis on encouraging partnerships among schools, government, and the private sector.

Encouraged by the public enthusiasm for science museums, many communities within the United States as well as other countries are planning or have recently established new science centers or a new educational emphasis for existing museums. These contemporary science museums are dedicated to improving the public understanding of science and technology. They provide a science education resource that is significant and not yet used to its full potential. Expansion of exemplary museum programs is possible through the creation of more incentives for schools and museums to work cooperatively, the establishment of ongoing funding support, and the formation of a body of research concerning education in museum settings.

Although we generally think of schools when we talk of science education, a growing amount of learning about science and technology is happening in informal settings outside the classroom. Widely available computer technology has made teenagers unchallenged experts at video games and whizzes on home computers. There are dozens of popular science publications, spanning a wide range of sophistication, from Scientific American and Science '83 to Popular Science and OMNI. Although "NOVA" remains the only regular TV series dedicated to explaining science, other programs like "The Body Human," "National Geographic," "Life on Earth," "Cosmos," and "Discover" regularly attract viewing audiences of 5 to 20 million (Tressel, 1982).

Science museums also attract huge audiences. Representing only 16 percent of the museums in the Nation, according to a 1974 National Endowment for the Arts Survey, they attract 38 percent of the museum-going audience (NRCA, 1974). A 1979 survey by the Institute of Museum Services reveals that science museums comprise 18 percent of the museums in the Nation and attract 45 percent of the museum-going audience (NCES, 1980). If zoos, planetariums, aquariums, arboretums, and nature centers are included, the total annual attendance is 150 million and equal to the combined annual attendance of professional baseball, football, and basketball games (Tressel, 1982). The National Air and Space Museum has an annual attendance of 10 million, approximately the same as Disney World and more than all the other museums of the Smithsonian combined (Tressel, 1980).

In recognition of the popularity of these alternatives that make science fun as well as educational, the National Science Board Commission on Precollege Education in Mathematics, Science, and Technology states in its preliminary report that "...there is evidence that many students who have an interest in mathematics, science, and technology are not being reached through instructional approaches currently used in the classroom. Whereas many students do not like school science—and form this opinion by the end of third grade—many do like the science and technology they see on television. They also like what they encounter at science and technology museums, planetariums, nature centers, and national parks" (CPE, 1982, p.7). The Commission advocates examining the innovative instructional approaches used at such institutions and, where appropriate, applying them to the classroom.

Many schools are capitalizing on the opportunity to "extend their walls" by working in concert with science museums. Traditionally systematic collection activities and related research have been the priorities of science museums. Today their role increasingly emphasizes informal education programs. Many contemporary science museums known as science centers have no collections at all in the traditional sense, but still value the use of objects to convey scientific knowledge and processes in a hands-on way.

The Association of Science-Technology Centers (ASTC) is a private nonprofit organization founded to represent science museums' common interests and to provide information and services to improve museum operation. Today the Association has 150 members, approximately 100 of which are science museums in the United States. ASTC provides a communication network through its conferences, workshops, newsletters, and other publications; a traveling exhibition service which manages a tour of temporary exhibits to about 50 different museums per year; and training opportunities for museum professionals. The Association is funded by member dues, fees for services, special project grants, and corporate donations.

ASTC's members are very diverse, from the huge Chicago Museum of Science and Industry, with its 14 acres of floor space, to the tiny Museum of Health, Science, and Industry in Cincinnati, which has 2 staff members and is housed in the former women's lounge of the Union Terminal train station. Half the members have annual budgets under one-half million dollars, and half were founded in the last 20 years. All are nonprofit and provide extensive education services to the public, including exhibitions, films, planetarium shows, classes for all ages, trips and tours, lectures, and special events. ASTC education programs include the following:

- 93 percent of science centers work directly with the local schools to provide educational services;

- 89 percent provide programs especially for teachers;
- 75 percent have outreach services that bring programs into the schools;
- 33 percent cooperate with universities to offer training for degree programs (such as graduate level teacher inservice training).

The following are examples of the education programs that science centers provide. They offer an update to the old stereotype of docents leading hoards of students on tours of halls past glass cases of musty exhibits. These programs are successful in their own communities and have potential for expansion and replication elsewhere.

Computer Programs

With the current hunger for computer literacy and the limited access to computer instruction in schools, science museums are experiencing a high demand for computer classes. Most science museums have followed the model of the Lawrence Hall of Science in Berkeley, offering literacy classes for all ages as well as opportunities for individuals to rent time on microcomputers. Whole school classes can register for lessons taught by museum staff in labs equipped with 15 or more computers.

A good example of the science museum community's response to this public demand is the Chicago Museum of Science and Industry's program. Their spring 1983 program catalog features 36 different, 5-session computer classes for anyone 10 years or older.

Several years ago, the Oregon Museum of Science and Industry in Portland initiated a computer club for gifted high school students. Working with an advisor, the students produced programs of commercial value for the local community. The museum's more recent efforts emphasize younger children's introduction to computers through classes for grades 1-3, using the Turtle graphics of LOGO and PILOT.

Last summer, Pacific Science Center in Seattle worked in cooperation with a local private school, which provided the facility, and several computer manufacturers, who supplied equipment, to offer a computer camp so popular that extra sessions had to be arranged. For a tuition fee of $175, students spent a week becoming familiar with computers and learning to use them as tools to analyze marine science data they collected at Puget Sound beaches.

In order to make their programs accessible to additional audiences, museums in San Francisco, Portland, and Seattle operate computer vans, and The Space Center at Alamogordo, New Mexico, plans to circulate one later this year. The Seattle computer van program has been selected for the National Science Teachers Association's top award this year in the "Innovation in Elementary and Secondary Science Teaching" category. The van brings 2 instructors, 15 Apple computers, and a variety of daylong lesson plans to public and private schools. Funding is provided by user fees and grants from foundations and corporations. Portland supplements their van outreach program with a Rent-a-Computer-Person service for groups needing an instructor versed in BASIC and PILOT.

Several centers offer workshops for teachers and administrators to provide basic computer literacy as well as to acquaint them with ways they can use computers to teach science and mathematics. Teachers need to learn how to select and evaluate software and courseware, how to manage classroom logistics when one microprocessor must serve many students, and how to use the computer to help with their own student assessment and clerical tasks. Pacific Science Center has provided this service under contract to the Washington State Superintendent of Public Instruction and for university credit. Other museums may offer their teacher classes independently or in conjunction with local districts. Chicago furnishes a choice of five different brands of microcomputers for their training programs. This gives educators the opportunity to compare hardware and software in a non-sales atmosphere in order to make more informed decisions about district purchases.

Teacher Services

An increasing number of science centers have established links with local university colleges of education to offer teacher inservice training. A common course offering is "How to Use the Museum in Your Curriculum" or "Using Science Resources in the Community" as well as many other special science topics in environmental education, astronomy, biology, social science, and energy education. Frequently offered for graduate credit, these courses not only use the special resources of the museum and its staff, but also often motivate an interest in science among teachers who avoided science during their previous schooling.

Teachers can obtain a more intensive science experience at the Discovery Place in Charlotte, N.C., the Pacific Science Center in Seattle, WA., and the Oregon Museum of Science and Industry. Elementary school educators teach and learn at the science center to improve their own science teaching quality and develop leadership skills to conduct inservice training for their colleagues when they return to their districts. This experience earns teachers credit towards a master's degree at several universities.

As well, museum educators recognize the important role that classroom teachers play in assuring that students make the most effective use of the museum. Teachers are encouraged to become acquainted with the museum through free admission incentives, educator open houses, introductory materials, and pre-visit workshops.

Equally as important as the museum visit are the followup activities. The Franklin Institute Science Museum in Philadelphia has developed the Science Enrichment Service, which are kits that teachers can take home to continue investigation of a scientific topic their classes studied at the museum. Each kit contains a poster, activity sheets, and a detailed teachers guide for further exploration. Other museums distribute children's publications, loan kits, and provide activity packets for additional followup.

## Curriculum Development

The Lawrence Hall of Science, part of the University of California at Berkeley, is a national leader in the development of science curricula. Examples of their published curriculum projects available for school adoption include: Science Activities for the Visually Impaired (SAVI); Science Curriculum Improvement Studies (SCIS); Outdoor Biology Instructional Strategies (OBIS); Health Activities Project (HAP); and others. All are highly motivational, involving students in the science experimental processes. In addition to curriculums, museum educators have developed computer software and courseware for classroom use, especially at the junior high level.

## Science Accessibility for Special Groups

Bringing science experiences to disadvantaged students, those with handicaps, or women and minorities is a priority of science museums. The Mathematics and Engineering Science Achievement (MESA) program at the Lawrence Hall of Science provides encouragement for minority students to pursue science careers. In a similar way, the workshops and curriculum materials of the Hall's EQUALS program give women students career guidance and incentive to elect mathematics classes in junior and senior high. These model programs have been emulated in other cities. Lawrence Hall also runs very successful Math for Girls classes in their weekend and summer enrichment program.

The Exploratorium in San Francisco offered workshops for parents, teachers, and administrators of disabled children. Workshop participants used the exhibits to experience the auditory, tactile, and vestibular perception problems often encountered by children with learning disabilities. This helped the participants better understand the problems faced by the children and taught them how to use Exploratorium exhibits effectively with them.

Pacific Science Center developed a curriculum guide and kits for loan to teach marine science to visually impaired children. The activities are appropriate for use by all children in mainstreamed elementary classrooms.

## Programs for the Gifted

Many science museums offer special programs for gifted and talented youngsters. Two exemplary programs are conducted in Atlanta and Baltimore. The Fernbank Science Center in Atlanta (part of the DeKalb County School District) holds a block of intensive science courses for able high school students. Bused to the science center daily for the whole term, the students have access to the electron microscope, telescope, nature center, and other special equipment facilities and expert staff at Fernbank.

The Maryland Science Center in Baltimore employs over 100-part-time instructors, many of whom are Johns Hopkins University professors, to provide science classes for academically gifted students who need enrichment and accelerated learning. Students are selected by IQ test scores, academic achievement, and recommendation to participate in these college level Student Science Seminars. The program is funded mainly by course fees.

## Outreach Programs

Since science museums are often located in urban centers, many programs emphasize exporting the museum staff and resources to more distant communities. Besides computer vans, several museums have teams of teachers, small exhibits, and "hands-on" lessons that travel in vans to schools for daylong programs. Others, including the North Carolina Museum of Life and Science in Durham, provide instructors and classroom-sized inflatable planetariums for conducting astronomy lessons that teach youngsters to use starcharts and to do their own evening observation activities. Available for travel from the Portland museum are "Tooth or Consequences," developed under the auspices of the Oregon Dental Association, "Clang, Bang, Toot—The Physics of Sound," "The Body Human," and other demonstrations geared to primary age children.

The Franklin Institute in Philadelphia is well known for its fine "Traveling Science Show" demonstrations on simple machines, chemistry, physics, and energy, which are conducted in schools by Institute staff. With the support of a NSF grant, the Franklin Institute also established exhibits and demonstrations in a local shopping mall. Their walk-through exhibit on mirrors and optics has been borrowed by the Science Museum of Virginia for display in the Richmond area shopping centers.

The Center of Science and Industry in Columbus, Ohio, uses students to spread science activities to the schools. Funded by the General Electric Foundation, the Young Experimental Scientists Program brings groups of five elementary students and their teachers to the museum for a day of experiments and learning and then provides materials for the students to repeat the activities with their classmates at school.

A group of dedicated volunteers and a grant from a Pittsburgh area printing company makes possible a children's hospital program conducted by the Carnegie Museum of Natural History. Volunteers visit the hospital weekly, conducting activities about dinosaurs. The program helps to alleviate some of the children's fear about a strange environment and the trauma of a stay in the hospital.

The Ontario Science Centre in Toronto sponsors a Science Circus which travels to remote communities in the province for 2-week stays. Their huge tractor-trailer transports 3,000 square feet of exhibits, a theater, and materials for workshops and demonstrations.

## Special Programs and Events

Science museum personnel are expert at devising creative programs to encourage learning about science and by necessity are also experienced at garnering the publicity, volunteer help, and financial support to sustain them. To follow are a few examples.

Seattle's Banana 500 and Boston's egg race are contests which encourage participants to propel vehicles carrying the "cargo" by using a rubber band or a mousetrap. These contests are generously supported by the media and provide good community visibility for science and recognition for inventive achievement.

The Camp-In at the Center of Science and Industry in Columbus, Ohio, provides an overnight camp experience at the museum for 35,000 youngsters and their scout or youth group leaders annually. Kids participate in science activities that they take home on topics such as cockroaches, crystals, and mathematics puzzles.

The Oregon Museum of Science and Industry maintains several resident summer camps, of which the best known is Camp Hancock in central Oregon. There campers use local study sites to explore geology, paleontology, botany, ecology, and astronomy.

The American Association for the Advancement of Science and ASTC are working together to identify and place in the community scientists who are willing to volunteer at science museums. In Durham, N.C., this program has resulted in the science center coordinating the placement of "visiting scientists" in elementary classrooms. The scientists receive some guidance concerning the abilities and learning styles of the kids as well as suggestions for activities in their fields that would appeal to the youngsters. The teacher and students get to relate to "real" scientists, dispelling some of the pervasive and erroneous stereotypes.

In Chicago and other cities, the local public TV station and the museum cooperated to offer teacher workshops on the topics covered in the following week's "3-2-1 Contact" program. Exhibits and programs at the museum were also coordinated with the weekly themes. Museum staff developed student activity sheets to focus a museum visit on topics from the program series.

These museum programs and many others not mentioned hold great potential for helping to address our current science and mathematics education problems. The following are characteristics of science museums that make them deserving of the funding and research support necessary to meet this potential:

1. Museums provide unique exhibits, facilities, new technology, scientists, and educators not available in the schools.

2. The informal nature of the museum environment allows learning opportunities that complement the classroom. Frank Oppenheimer, Director of the Exploratorium, explained, "No one ever flunks a museum....In contrast to classrooms, museums provide a reversible, deflectable, 3-dimensional form of education" (Oppenheimer, 1979, pp. 8-9). In his opinion, museums are voluntary, entertaining, and necessary artificial environments for learning.

3. The museum's general focus on public understanding and appreciation of science and technology seeks to create a level of science literacy and enthusiasm in the community in which school science program initiatives can flourish. For instance, families that attend science museums start their preschoolers early with activities to enhance their children's interest in science.

4. Science museums have a heritage of working with schools, businesses, community groups, and governmental agencies in the collaborative manner dictated by today's economy. They are experienced at attracting volunteer help and media support.

5. Major museum exhibit programs are cost-effective. The National Science Foundation discovered that the costs and potential audience of successful science exhibits are directly comparable to the costs and impact of a public television program--usually pennies per person (NSF, 1983). Programs such as the Association of Science-Technology Centers' traveling exhibition service enable costly exhibits built by one museum to tour museums in several cities, increasing the potential audience more than tenfold. The Exploratorium publishes an exhibit "cookbook" that many museums use to build their own exhibits without costly development and design outlays.

In recent years the value of science museums as an adjunct to formal education and a catalyst for scientific and technological achievement has been recognized by leaders of many communities here and abroad. In the United States there are numerous small science centers being established, many by Junior League volunteers, parents, and educators. New science centers are starting in Canada, France, West Germany, China, Japan, the Philippines, Malaysia, Indonesia, Australia, India, Saudi Arabia, Nigeria, Israel, and in other nations striving for technological improvement. To accommodate this growing trend, ASTC recently created a new category of membership for developing museums not yet open to the public.

These fledgling science centers and the ones that currently exist will have a much greater impact on improving science education if several challenges are addressed:

1. Partnerships--More incentives are needed to get schools and museums working together enthusiastically and for mutual benefit. Establishing successful partnerships requires a substantial investment of time and resources initially to identify the participants, communicate needs, inventory resources, set goals, and arrive at a firm commitment. This process does not happen magically and may take considerable effort and funding even before the actual cooperative project is undertaken. A first step is to improve communication between schools and museums through participation in each other's curriculum and education advisory committees, at board meetings, and through Parent-Teacher Associations, and other professional meetings. In addition to their boards of directors, some science museums have education advisory committees to suggest the museum's program priorities in relation to the community needs. School administrators and teachers serve on these committees, assuring good school-museum cooperation. Likewise, museum personnel should support school district planning activities.

2. <u>Funding</u>--Most science museums struggle constantly for support, relying largely on earned income, business and individual donations, and, to a much lesser degree, on Federal grants and municipal support. With the exception of the modest funding from the Institute of Museum Services, funding from the National Science Foundation and other agencies has been for specific projects of limited duration. Support for developing innovative programs is vital, but it does not encourage sustained program efforts and may even exacerbate the museum's basic need for operational funds. How do we assure museums' basic support level so that museums can afford time to fundraise for new programs?

3. <u>Research</u>--The body of research that exists in other areas, such as education, can contribute to what is known about the effects of science education gained in the museum setting, but this must be done very carefully and systematically. Research models developed for the school setting may not be suitable for science museum activities. The informal nature and novelty of the museum environment and the short duration of contact many visitors have with museums must be considered. More research is needed specifically about museum practices and about the long and short term effects of science museums both cognitively and affectively. Do museum field trips make a difference in classroom learning and behavior? Are there more gains for one type of learner or teacher than another? How effectively do exhibits communicate their messages? What kinds of program designs work best with family groups or very young children?

It would be a tragic waste not to overcome these hurdles and fully tap the special resources of science museums to help address this Nation's complex science education crisis. Joel Bloom, Director of the Franklin Institute, reminded us at the National Academy of Sciences Convocation last May that "science museums present information...They excite people...Museums let people learn in their own way, at their own pace, at their own schedule" (Bloom, 1982).

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# POLICY ALTERNATIVES: EDUCATION FOR ECONOMIC GROWTH

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## The Problem

Providing high quality mathematics and science instruction constitutes a serious challenge to our Nation's educational success. This is particularly significant at a time when it is essential to train our future workers for increasingly technical and skilled jobs and to raise the general scientific and mathematical literacy levels of our country's future citizens. Our technological edge is threatened by a shortage of skilled engineers and scientists. Technological literacy is also becoming increasingly important for full participation in our society and for individual personal development. Literacy in a technologically-oriented society will depend upon knowledge of the basic concepts of mathematics and science and an understanding and demonstration of their applications.

Not only are experienced mathematics and science teachers leaving the profession for more lucrative jobs in business and industry, but the number of entrants into mathematics and science teaching has declined over the past ten years. Many states are experiencing teacher shortages in mathematics and science and, as a result, uncertified or temporarily certified teachers are sometimes filling the gap. This solution may appear pragmatic in the short-run, but it is detrimental to raising the quality of instruction in these highly demanded areas.

## National Task Force on Education for Economic Growth

In response to the severity of the mathematics and science education dilemmas facing our country, including teacher shortages as well as other areas, Governor James B. Hunt, Jr., of North Carolina, Chairman of the Education Commission of the States (ECS), established an ECS Task Force on Education for Economic Growth.

Forty national leaders compose the Task Force, including governors, legislators, heads of major corporations, education officials, and representatives from labor and the scientific community. Additional representatives from each of these sectors provide a network of knowledgeable advisors to the Task Force.

The Task Force is action oriented, drawing heavily on relevant data and resources that already exist. Its focus is targeted on strategies to improve the quality of high school education, especially the skills required for economic growth. The Task Force gives momentum to the growing interest and concern among governors and corporate leaders for the quality of our public schools.

Specifically, the goals of the Task Force are to:

1. Create national understanding of the need for a better educated work force that is necessary for economic growth.

2. Report on how well current education programs are preparing youth for future jobs.

3. Identify alternative policies, programs, and actions to improve education which may be used by national, State, and local leaders in both the public and private sectors.

4. Promote partnerships among community, business, labor, government, and education leaders to improve education leading to economic growth.

Although its focus is on education for economic growth, the Task Force remains cognizant of other equally important purposes of public education, e.g., citizenship and personal growth.

Survey of State Initiatives in Education

The initial activity of the Task Force was directed toward governors as the officials responsible for guiding State leadership. A State survey developed by ECS staff requested all governors to report the programs and activities underway in their States that address education problems and opportunities.

The governors were asked to provide information on activities concerned with:

- improving student competencies in mathematics, science, computers, and other academic areas;
- using computers to improve education;
- providing incentives to attract, retain, and upgrade education personnel, particularly in science and mathematics; and
- involving citizens and business and industry leaders in education.

Almost 40 states have responded to the survey to date. Although each State reported a unique set of initiatives for each problem area, most of the responses fit into one of three categories.

- Task forces to study the issues; define the problems, needs, and opportunities; and recommend new policies and programs. Task forces focusing on teachers are examining issues such as the structure of the teaching profession, the nature of teacher training programs, and the future supply and demand of teachers.

- Programs to enhance the quality and quantity of curriculum, facilities, students, and teachers.

- Programs to encourage broader involvement in education by citizens, business, and industry. In the area of teacher shortages, the survey shows that States are initiating strategies to recruit and attract new teachers, such as scholarships, loans, or differential pay for mathematics and science teachers. States are also implementing programs to supplement the work of current teachers, such as staff sharing, special summer programs, and alternative instructional arrangements (see the policy alternatives presented in the next section for more information on these programs).

Based on the results of this survey and a follow-up survey, the Task Force will assemble a set of recommendations to assist States in assessing their current programs, in designing new and improved programs, and in formulating their legislative proposals over the coming year. The followup survey will request more specific information on the types of issues being studied, timetables for action, and proposed recommendations. Possible target groups for the second survey include State education agencies, legislators, and business/education councils. The recommendations will be encouraged for use by educators, government, and business/industry officials. In addition to the surveys and recommendations, the Task Force is considering a full range of alternative products: resource documents describing the nature and magnitude of the problems confronting education, legislators, and business/industry officials; a series of awareness/action brochures for State leaders; a national public information and awareness program; audiovisual presentations; and other products to be determined by the Task Force members.

Recommendations--Education for Economic Growth

The Task Force met in Washington, D.C., February 26, 1983, to address strategies for improving the quality of high school education, especially the skills required for economic growth. The Task Force reviewed a preliminary set of policy alternatives, which were previously shared with participants of the NIE Conference on Teacher Shortages in Science and Mathematics: Myths, Realities and Research on February 8-10, 1983. A copy of this earlier presentation may be obtained from John Taylor of NIE or from Roy Forbes of the Education Commission of the States.

In addition to modifying many of the policy alternatives, Task Force members agreed to work toward developing specific recommendations tailored to key sectors. The sectors identified thus far are governors; Chief State School Officers and State Boards of Education; and business and industry leaders. The remainder of this paper presents the draft recommendations for each of these three groups as well as a set of recommendations entitled "Partnerships," which presents suggestions for action across all groups.

Throughout the next two months, the Task Force will develop recommendations for additional groups, including State institutions of higher education, legislators, and parents' organizations. In addition, separate sets of recommendations will be developed for Chief State School Officers and State Boards of Education. The recommendations for the business/industry sector will be expanded.

The final meeting of the Task Force is scheduled for May 4, 1983. Prior to acceptance by the Task Force of the final recommendations, appropriate agencies and sectors will have an opportunity to review their respective sets of recommendations. The reader should keep in mind, therefore, that the recommendations presented in this paper will be further revised.

TASK FORCE ON EDUCATION FOR ECONOMIC GROWTH—
Actions for Governors

The key action for Governors is to assume a strong leadership role in supporting educational improvement in concert with State boards of education, chief State school officers, higher education authorities, and State legislators.

1. Establish a State level Task Force consisting of leaders from elementary, secondary, and higher education; business; government; the scientific community; and other concerned parties to:

   a. Examine the current status and needs of public education, especially in science and mathematics.

   b. Set State priorities and goals for improving education.

   c. Recommend programs and policies to improve educational programs.

   d. Mobilize public concern and commitment to improve public education.

2. Take a strong leadership role in promoting working partnerships at the State and local level among parents, community leaders, businesses (management and labor), governments, educators, and the scientific community to strengthen education.

   a. Invite business/industry to work with schools in developing strategies to upgrade course curricula, increase pupil enrollment and performance, increase the supply and quality of teachers in critical fields, and improve the public understanding of the need for greater investment in education.

   b. Work with the State legislature and/or private industry to provide seed funds to local school systems to establish local education resource teams consisting of representatives from the above groups and given the mandate of using local resources to significantly upgrade the quality of education.

3. Work with the legislature and/or State board to adjust certification requirements to ensure that teachers are qualified in both content and methods in their areas of instruction.

4. Work with State authorities to establish a deadline by which <u>all</u> teachers must be certified in their fields of instruction. Then, provide funding to implement training programs for teachers at all levels which will enable them to attain certification in their fields by the deadline. The programs could be established in a number of ways:

   a. Summer institutes operated by institutions of higher education.

   b. Provision of grants to support tuition and fees for college courses offered during the summer or in the evening.

   c. Extension of employment in order that teachers may remain employed during the summer months to work on certification in teacher shortage areas, special curriculum projects, participate in intensive training programs, or upgrade their technical skills.

5. Seek funding to provide summer employment for lead teachers and teachers in critically needed subject areas to work during the summer and develop new curricula, teach courses, train new teachers, work with community leaders on school improvement projects, and improve their own instructional and management skills.

6. Work with State and local boards to provide special awards for outstanding teachers in various subjects and levels and for administrators with recognition and substantive rewards (e.g., professional perks, sabbaticals, education grants or cash bonuses).

7. Work with State boards and the State education agency to establish a statewide <u>curriculum study committee</u> consisting of educators in various subject areas, business and civic leaders, experts on new and emerging technologies, etc. The objectives of this committee will be to:

   a. Evaluate current curriculum goals and standards.

   b. Determine competencies students will need to participate effective in the workforce and public life of the future.

   c. Update and strengthen curriculum objectives, especially in science and mathematics.

   d. Develop a plan for computer utilization in the school curriculum.

8. Establish a statewide testing commission which can work with local school districts (LEA's) to:

   a. Set standards and assess student performance at key points throughout the student's career; focus on basic skills and prerequisites.

   b. Identify student deficiencies early and require effective remediation.

   c. Provide encouragement for programs of academic excellence for all students.

9. Work with your State education agency and local districts to develop programs which promote and reward student achievement.

   a. Establish a "scholars" program which rewards students who enroll and excel in courses that exceed the minimum required for graduation.

   b. Create summer institutes where advanced or disadvantaged students can have specialized instruction in particular areas of need.

   c. Establish alternative schools at the State or local level where students can move to develop higher level skills in specialized areas.

   d. Establish a variety of academic competitions for students and provide recognition, awards, and prizes for high achievement (e.g., mathematics and science olympics, writing contests, problem-solving competitions, etc.).

TASK FORCE ON EDUCATION FOR ECONOMIC GROWTH
Actions for Chief State School Officers and
State Boards of Education

State leaders having primary responsibility for the operation of State elementary and secondary school programs are the State board members and the chief State school officers who direct the work of the State education agency. Much of the work of the State board and the chief State school officer requires the involvement of the State legislature, the governor, State teacher administrator training institutions, and local school leaders. Examples of things that chief State school officers and State boards of education can do are:

1. Work to establish and fund a State mechanism for educational R&D in areas critical to improving your State's educational programs

   a. Study and implement projects involving fundamental changes in the occupation of teaching, e.g., differential staffing, new reward structures, or new evaluation models.

   b. Implement models of teacher and administrator evaluation involving peer review, state of the art standards, and rewards as well as sanctions.

   c. Fund curriculum development and testing in critical areas—science, mathematics, computers, economics, career awareness, writing, problem solving, etc.

   d. Assess statewide equipment and supply needs in science education and determine the level of support needed from the State level; provide matching funds (i.e., 70-30) from the State for science laboratory equipment and materials.

   e. Study the changing role of the teacher and uses of the computer and other new technologies in science, mathematics, and other disciplines; develop a State plan for computer utilization in education.

2. Work with the State legislature, institutions of higher education, and private funding sources to provide scholarships and loan forgiveness programs for teachers in critical shortage areas, i.e., science and mathematics.

3. Work with local districts to establish an aggressive recruiting program for high quality prospective teachers—especially in critical shortage areas.

4. Work to establish periodic professional sabbaticals for outstanding career teachers.

5. Establish State teacher/administrator certification and recertification standards and guidelines which are rigorous and relevant.

6. Modify certification requirements to permit people with special expertise from industry, academia, or professional organizations to teach on a team, part-time, adjunct, or shared basis and encourage local districts to use these resources.

7. Establish administrator certification requirements for the inclusion of management theory and experience as a precondition for school administration.

8. Provide increased time for instruction through State funding, accreditation, and college entrance requirements which result in:

   a. Lengthening the school year.

   b. Lengthening the school day.

   c. Decreasing non-instructional demands on teachers and class time through the use of clerical aides and better management techniques (computers, etc.).

   d. Decreasing non-instructional demands on students.

9. Recognize and reward teachers and administrators who exhibit outstanding instructional and managerial leadership.

## TASK FORCE ON EDUCATION FOR ECONOMIC GROWTH
### Actions for Business and Industry

Business and industry leaders may play important roles in renewing and supplementing our education and training systems. Specific actions that may be taken are:

1. Establish collaborative programs between teachers and persons from business/industry for shared staffing, training, and exchange opportunities.

   a. Establish exchange programs between business managers and educators.

   b. Encourage interdisciplinary programs at post-secondary education levels between schools/departments of education and schools/departments of business and public administration.

   c. Establish programs for teachers to work as interns in industry and for industry officials to serve as part-time instructors in public schools.

2. Share or loan personnel to participate in team teaching of sophisticated technological concepts.

3. Provide aides, volunteer and paid, to assist in instruction and to reduce teachers' non-instructional responsibilities.

4. Loan, donate, or sell equipment and provide personnel to schools or school systems. Personnel support might range from volunteer tutorial programs for both disadvantaged and advantaged students to regularly scheduled instructional opportunities for industry officials.

5. Recognize and reward students and teachers who are judged to be outstanding.

6. Provide the use of company/college or university training facilities where it would not be cost efficient for school districts to build and equip comparable sites.

7. Provide laboratory space for teachers or students to carry out experiments, preferably with guidance and support from industry or university officials.

8. Provide support for community activities which contribute to education. For example, provide small grants to libraries, nature and science museums, public gardens, art museums, etc., in order that these institutions might establish special instructional facilities available to the general public and be accessible to students during the school day.

9. Provide resource materials and curriculum assistance to public school science and mathematics programs, e.g., special units on topics such as energy conservation, robotics, industrial processes, etc.

10. Involve students in programs such as Junior Achievement, to acquaint them with the economic system.

TASK FORCE ON EDUCATION FOR ECONOMIC GROWTH
Partnerships: Actions for Joint Implementation by Government, Industry, Academia, Professional Associations, and Schools

Collaborative action among the political, business, educational, and public leaders of the State is critical to renewing our education and training systems. Specific actions that may be taken are:

1. Participate in local decisions on education programs and policies.

   a. Establish a clearinghouse for partnership information designed to serve parents, community, business, labor, government. educators, and the scientific/engineering community.

   b. Develop and disseminate information packets on how to develop and operate efficient and effective partnerships.

2. Promote programs linking schools to business, academia and professional associations:

   a. Encourage industry/professional societies to sponsor science fairs and judge student research projects.

   b. Jointly sponsor, at the local level, annual Education Olympics programs, whereby each school puts together a number of teams to participate in educational competitive events. The model for such a program is the athletics program at each school.

   c. Establish a "Retired Scientists and Engineers" program, whereby those who have retired but wish to remain active in education can be called upon to provide specialized instruction.

   d. Establish summer internships for students and teachers to work in industry, government, or university laboratories.

   e. Sponsor, in conjunction with other local industries, an ongoing series of forums for parents on the role of education in preparing youth for employment and citizenship.

   f. Establish adopt-a-school programs which link businesses to schools.

g. Assist in training teachers and administrators in the uses of new technologies.

3. Provide rewards and incentives to attract and retain capable professionals.

   a. Establish scholarships, grants, graduate fellowships, other forms of tuition assistance, and forgiveness loan programs for both new and current teachers.

   b. Offer financial awards or training funds to school staffs or individual teachers who are recognized as outstanding by their peers.

   c. Develop an "Excellence Recognition Program" which provides outstanding teachers and administrators with various forms of community recognition and financial rewards.

   d. Provide incentives for qualified business and industry personnel to teach in mathematics, science, and other technological areas.

4. Provide laboratory space for teachers or students to carry out experiments, preferably with guidance and support from industry officials (management and labor).

5. Actively encourage the participation of women, minorities, and other students in mathematics and science.

   a. Develop special scholarship programs for women and minorities.

   b. Distribute to teachers and students materials designed to encourage women and minorities to enroll in more mathematics and science courses.

   c. Establish "Mentor Programs" in which students work as technical research assistants in industry, college, or government laboratories several hours per week and during summers.

6. Increase student awareness of career opportunities.

   a. Provide information to administrators, teachers, and counselors that can be used to help students plan for careers.

   b. Invite local business and industry officials to schools as guest speakers to describe the nature and extent of career opportunities in the State.

c. Develop a cooperative summer job program to provide students with understanding and experience in a variety of careers.

d. Arrange for groups of students interested in particular careers to visit relevant organizations with their parents.

7. Establish formal programs which enable secondary students to receive advanced training in science and mathematics by enrolling in courses at nearby colleges and universities. Students should receive academic credit for their work.

# DISCUSSION OF PUBLIC AND PRIVATE SECTOR RESPONSE TO THE TEACHER SHORTAGE IN SCIENCE AND MATHEMATICS

Lynn Gray, Vice President of Education,
New York Urban Coalition

I think I need to tell you a very short story to begin what seems to me to weave through a lot of my remarks. The story is a story of a little mouse. This little mouse lived in a very, very large mansion. He was an extremely fortunate mouse. He had the run of the entire place. And as life would have it, he gradually set up a network of really beautiful support systems for himself, enjoyed happiness--you know, just about the happiest mouse you could imagine.

Then one day something entered that mouse's world which was so unfathomable and terrifying it really began to shrink all the possibilities of the mouse's world. You can guess--it was the world's most ferocious cat. And this cat gradually, on a day-to-day basis, began stalking the mouse.

Little by little, the mouse's world shrank and shrank and shrank, until finally he was holed up in a little tiny hole in one of the baseboards in a second-floor room. It sat there for days at a time. It couldn't figure what to do. Finally he decided, "Well, I'm done; I'm dead," and he began to think of whatever the next life is supposed to be.

He was sitting in sort of a melancholy state when he heard the world's most incredibly exciting sound. He said, "I don't believe my ears." He heard the most gracious sound imaginable--the ferocious bark of an incredible dog.

And he listened, and he said, "I don't believe this." And he listened and listened and, sure enough, the bark was powerful, and the cat had obviously run away.

The mouse said, "What am I going to do about this?" He thought, "There's one place I stashed the perfect piece of cheese." So he decided, "That will be my first trip."

So the mouse stepped out of his hole and began trotting across the room in order to get the cheese and found itself caught in the furry paw of the world's most ferocious cat, and was just stunned and sad. The cat held the mouse out and said, "Gotcha."

The mouse was puzzled, and the cat said, "Look, before I do you in, is there anything you want to know or anything you want to say?"

The mouse said, "Yes, there is basically one thing. What about the dog?"

And the cat grinned and said, "You know, sometimes it pays to be bilingual."

Now, I am really going to connect that to my comments—I really am. I wanted to connect it once in a simple way. I was saying to a friend of mine at lunch that there is something powerful going on in a room like this. The different languages and the different orientations that are in this room are powerful. There are researchers, scientists, school people, practitioners, et cetera. And those of you who have been going to meetings like this over the last decade or 20 years know that that is a new kind of phenomenon, where we are actually trying to have dialogue among people who look at the same problem, but look at it from very different perspectives and need to learn to speak with each other and to each other.

The second thing that struck me this morning was people pointing out how children lose their excitement about science between the third and the eighth grades. I thought of the junior high school that's a block from my house in New York City where I was sure that last year I must have seen maybe a thousand Rubik's Cubes—millions of kids spending hours and hours and hours playing with what is a scientific and conceptual mathematics device. They were extremely stimulated. They didn't know they had lost an interest in science or that they weren't able to handle it. What they probably were experiencing was what had not been in their daily life in the school—the kind of excitement that caught them. They spoke a different language than the one they were being asked to respond to.

The third thing is that there is a bilingualism that is being promoted by the President. That would surprise him, wouldn't it?

It's the public/private sector dialogue. And this panel is talking about that. This panel is saying that there is public sector schooling and there is private sector resource and private sector need, and that some way these things have to come together. In reading the papers and in hearing the presentations, you take in a huge range of particular things that are being done in two kinds of situations, followed by the Education Commission of the States (ECS) survey of what really needs to be done on the national level.

I want to comment on that stuff, but I want to put it in the context of a comment that Dean Kelly made this morning because it reminded me of something else that was a working rule of thumb in New York City. His comment ran something like, "Bureaucracies have an almost absurd capacity to swallow innovation without producing change."

We had a working rule of thumb in New York City a few years ago—we've gotten a little better since then—that went like this, "Every single day, someplace in New York City, every conceivable educational innovation is going on and having very limited impact, and not spreading from one site to another." It wasn't for lack of new mousetraps that we were being overrun by mice. It was for lack of understanding how to implement these things in existing systems and how to build with our existing resources—our teachers, our professionals, our communities—in order to take advantage of what was there.

That happened a few years ago. That is all catalogued under research that says schools have a remarkably difficult time incorporating change, that there is a lot of stuff that is supposed to be good, that a lot of people say is good, that a lot of people want to have happen that doesn't happen. And there are all sorts of supporting data, and NIE is a repository of a lot of it.

We are not in a different situation just because we are talking about mathematics and science.

We have changed in New York City. I can stand here and be genuinely proud of the movement in our school system over the last several years. We have turned around all sorts of trends. We are doing better on formal tests, et cetera. But listen to this! Still we have a million kids, 45 percent of whom drop out of high school; 60 percent of the Hispanic kids drop out of high school. We have 250,000 of what we call ghosts. These are kids that nobody knows the whereabouts of except that they are in our city. They don't show up in school. They are in between the ages of 16 and 20, 15 and 20. They are there. We have 60,000 kids who are not mathematics and science illiterate; they are just illiterate.

I think one of the things that always sobers me is listening to a lot of connections between different resource mixes. The Argonne thing, for example, where there is a program of 15 kids who are going to do such and such. I applaud it and I think it's incredibly powerful. But we really are talking about a very awesome reality when we talk about major school systems. And New York is really not atypical. You heard the Los Angeles story this morning and the Houston story, et cetera.

So I just want to remind us that what we are talking about is a set of interventions with children--and there's a lot of them--and what we have to do is find ways to get this particular agenda into a lot more lives than we have been able to previously with the resources that are available. It is reminiscent of the response of the private sector to the current administration when it said, "You will now handle social programs." Thanks, very much. We can be committed. We can make linkages, but don't expect us to do what couldn't be done when there was a lot of other stuff going on.

The comment, "No one flunks a museum," triggered something in my mind. I used to run a bunch of alternative schools in New York City. One thing I discovered was that when it got really boring in the school, if you wanted to know where to find the kids, you went to the museum. Because lots and lots of kids almost magnetically went to places that were exciting.

Now, they didn't flunk, but they never got credit for it, and it never got built into their experience. By itself, it probably provided stimulation, but all alone it really didn't do what has been called for. The kinds of things that are called for in these linkage programs are ways in which new resources and different conceptualizations can really infuse the experience of kids.

In my view, what went on in this panel broke down as follows:

I think we have examples of two particular innovation patterns and then a large policy study that is right on target for some national policy questions: the public/private stuff, the mathematics and science stuff. I think that it's about alternative and augmented resources to large school systems. These are the places where the kids really are. The New York City public school budget is $3 billion every year. Chicago's must be $2 billion. We've got a million students and Chicago has about the same. So we spend a lot of money in this country on schooling.

The alternative supports, the vision that is evident in things like the Argonne Laboratory wanting to infuse the entire Chicago school system with a better approach to mathematics and science—that is exciting. The problem of actually doing that and having enough leaven to actually affect the whole loaf is really, I think, a very tricky reality and something that has to be addressed here.

I want to underscore how exciting it is to find again in this country in the private sector and nonpublic school environment people reaching out to the schools. I think the comments in one of the panels this morning about public education becoming upbeat finally is noteworthy and true. I just want to put that note of caution in.

I want to tell you two stories that summarize something for me about schools.

One comes from back in the 1960's, and we weren't talking about mathematics and science then. We were just talking about urban problems. We were talking about trying to enfranchise people. The late 1960's in our urban centers were a period of a huge outpouring of corporate American resources to schools. In New York, we had 19 corporations that sponsored schools by themselves. By the mid-1970's, we had two.

It wasn't that the corporations turned into bad guys and walked away; it was that over and over and over again the experience of the private sector in trying to make that link went something like this: "We thought we came in to work on the problem of"—I'll put it in today's concepts—"mathematics instruction at the high school level. We got into the school and found that the level of problem in the school organism, the school situation, was so vast that in many cases we were trying to recreate the whole school, and we were not able. We were not able to give what we had, and we became discouraged and left."

If you look at the history of the 1970's in urban America, you do not have a lot of corporate presence. You have little places where it has lingered about the school programs, but there was really a pulling back. And I think one thing that was a major factor in that was the inability of the school system to honorably make the linkage, and to understand what it meant to bring in somebody else with a particular kind of resource, and to meet them much more than halfway so that the benefit got to the children.

I have a colleague who today is in El Paso, Texas, on a Ford Foundation study. They are looking at exemplary high schools across the country. El Paso is one of many cities that has nominated several of its programs and said, "We have exemplary high school education."

I was talking to my colleague on the phone last evening, and she said, "Let me tell you the story. I went into the school"--and I don't know the name of it--"and it's got a very strong reputation. It is supposed to be very exciting and very innovative and really work with kids."

Her task was to interview all sorts of people, sit with kids, sit with teachers, et cetera, to see what it was like, how it felt. She said, "I was really stunned because every single time I asked this question I got a blank look back. I asked the question, 'What is it that makes your school so special?' and nobody could answer."

First of all, they didn't feel they understood the question; they couldn't factor out, they didn't know how to talk about interrelationships in the building. Second, they really didn't grasp she was struggling to understand the larger mission of the school.

But there was a sense in that building: "This is just a building. And special? I don't know." She said the feeling in the building was pretty good. It wasn't a great, great school; it wasn't a bad school. But it was just her sense that the people who were in there didn't apparently think, "We are a collective body of people working with a group of kids, and this is how we are doing it. This is how we come together on their behalf. This is what we are targeted toward."

The Houston story with the incentives--the $800 incentive, for all that it might mean about special school districts--struck me as interesting because everybody in the building working with all those kids was included in that process.

I want to make two or three comments about partnerships and about linkages, because I think they are going to be central for the next 10 years of our work for sure.

The first is that it is often a very difficult matter arriving at a commonality of goal and direction between museum, Argonne Laboratory, IBM, whoever it is, and school system and school. The language difference, "the bottom line," as was said this morning by some gentleman--all of that stuff is just two different worlds. Until we have sat down together and worked through this material over an extended period, we really waste a lot of resource and a lot of energy. The problem is that in most cases we think we understand each other way before we do. It will take significant attention to the process of getting started if we are to have any chance of making an impact.

People have walked away from most of the projects we have seen because they thought they knew what they were going to do before they actually did. And they got in there and they got very disillusioned. They didn't know how to have followup; they didn't know how to talk. They expected something from the school that it couldn't deliver. They expected something from the corporation that it didn't want to give.

There needs to be a tremendous amount of attention paid to beginning these things gently and carefully. Science is obviously a need in urban schools. For me, it is just really sad to see the number of hours that our high school kids are not in school, and the number of hours they are in school and not excited about learning. They are not bad or dumb or dull kids. We are just not putting stuff in front of them and working with them in a way that is stimulating them. But if we bring something in, an Adopt-A-School project, for example, and we don't work this stuff out, we're going to lose the students and our mutual effort.

Secondly, I would offer a comment about school teachers. And I think they are some of the most remarkable people in the whole universe. One thing that is fairly true about them is that most of them have never been outside the culture of the school. Most of them have not been in the private sector; they have not been in the work force outside of the school thing. Their expectations of what they are trying to match in their classrooms are not framed out of a realistic personal experience.

Atlanta has taken groups of teachers and put them in the private world to let them experience it, with no goal--not so you come back and do such and such, but just so you know, so that you are not limited. If you are going to be the bridge between our children and this world, make sure you have experienced it.

Under the mathematics and science heading, somebody commented that you don't see science teachers do science. Probably most science teachers in public education don't do science, haven't been around anybody doing science, and wouldn't like to do science. But that connection is very profound because we are trying to get the imagination of teachers to stimulate the children.

The third thing is the clarification of roles. I guess I alluded to it. Very often the level of false expectation between people in these mixes is astounding. I just want to call attention to that again.

The fourth thing is the timeline. In the Argonne paper the comment was, "We have a timeline. We are not up to it yet." And when I read the paper, I particularly noted three phases: We are going to start, we are going to expand, and then we are going to do the whole system.

We have been working in New York City now on a couple of educational innovations, and we are in our 15th year, and we are finally starting to move into maybe 30 or 40 percent of the schools. We may not be very smart, but it isn't going to happen inside of a real short time. There's a lot of stuff that has to be laid out thoughtfully and carefully.

My last comment is a bottom-line comment. One of the things that I think happens in these partnership linkages is that we spend a lot of time thinking of the roles and relationships of the various players, but we have not learned how to focus on the children and what they really need.

One of the things we are starting to talk about in New York City is what we call an "Accord for Youth." An accord means that all of the players--all of the people like us who really have some stake in our kids, whether we teach them or, as community people, we need to hire them--come together and actually make commitments among ourselves to pool resource, imagination, and commitment, to see that these kids get the kinds of things they need. So we really begin to think over time of reshaping our relationships, not just so one augments another, but so that we really say, "What do we need to get the junior high school kids so they don't disappear from us? What kinds of experiences can we give New York City's 200,000 junior high school kids so that we don't lose 100,000 of them in 4 years, and so that a lot of them don't end up at a much lower level of development than need be?"

My summary, I guess, is something like this. I think that one of the most upbeat things that is going on nationally now is this public/private possibility. I think the mathematics and science thing is a symbolic and very important way for us to work together on it. I think that it can build some things that are very powerful, but it doesn't do it automatically. A lot of these things are going to be built on the passion of the people that are here; they are going to be built on the luck of some of those that try it. But we are talking about sustaining major growth for kids all over our country, and that's going to take a huge and attentive kind of awareness.

# CLOSING SESSION

Thomas Good, Professor of Education and
Assistant Director of the Center for Research and Social Behavior,
University of Missouri

It is good to be here and to be part of the conference. My compliments to those of you who have stayed through 2 days of proceedings.

My colleagues and I represent four captives who have lived through 2 exciting days listening to many presentations filled with ideas, problems, dilemmas, contradictions, but all-in-all an exciting set of papers.

Our intent here is not to synthesize or to put what we have heard into a simple caption, but rather to probe through the possibilities, to look at the ideas that have been presented and, if anything, to widen the funnel of possibilities that have been examined here so that in future activities, in terms of responding to the problems, we end up with a wider information base and a better response.

At this point I turn to my colleagues, who will have the opportunity to respond to the ideas, what they heard, what they felt, perhaps some of the things they did not hear here at the conference.

Robert Stake, Professor of Education
Center for Instructional Research and Curriculum Evaluation,
University of Illinois

Tom, you asked what we had not heard at this conference. No one mentioned Creationism. Perhaps everyone thinks that crisis is over--but we all know that evolution and adaptation of science and mathematics education goes on.

I was impressed by Wayne Welch's recommendations for needed research and agree that the student classroom activity and contexts need more attention. I will emphasize those today in my remarks, though my primary attention will be on visions of the science teacher.

Let me start with a theme that Jim Wilson and Jeremy Kilpatrick emphasized, and many others have alluded to in this conference: Success in public education depends on teachers with vision and a public vision of teaching. But the vision changes. A vision of teacher as Miss Jean Brodie is out of a past to which we cannot return. The television vision of teacher as Welcome Back Kotter is a compassionate but mindless vision we cannot accept and must fight against. The vision of Bob Gagné of teacher as behaviorist and preparer for testing is a vision that, in my opinion, both denigrates education and the teaching profession. The vision of teacher as curriculum developer--if that means developing lessons that other teachers and districts would use--should have been destroyed by Commissioner Sidney Marland's farcical and never completed program, Education for the Eighties, which once gave 17 school districts the responsibility for building a grassroots curriculum for the Nation. But there are other meanings of curriculum development and behavior management, such as compassionate elder and ideological guide, that are enduring and needed. They have been referred to by Susan Veitch, Lynn Gray, and others at this conference.

I was greatly struck by Secretary Bell's remarks. He got us off on the right foot by drawing attention to the changing nature of our society and giving us reminders of the power of culture, including the economic and political realities that shape education. Precollege education--including mathematics and science--are held in diminished regard by the public. There is no indication that taxpayers are having second thoughts about the cutbacks in funding for education. Several here have called for a media blitz, scholarships for teachers, and even increased pay. They are needed and may help. But we cannot go much further with the idea of the "competent teacher in front of a class." We cannot effectively retain the old vision, the myth, of a teacher as knowledge-giver. Knowledge getting already has shifted to other channels.

What Terrel Bell did not say is that high technology will change the very nature of knowledge--not just its transmission. What is worth knowing will change, what will be considered as evidence will change. What a computer can store will become more important. History will become more actuarial, less anecdotal. The kind of interpretive knowledge to be found in a good textbook or in the lecture of a good teacher will continue to be replaced by 2-minute summaries mimicking those on Cable News Network. The teacher increasingly needs to be reactor, commentator, and director of continuing learning.

What is lost already is the notion of teacher as knowledge-giver. And it can't be regained. The tactic followed for at least a decade now has been to reduce the "contractual" task of the teacher, the syllabus for the teacher, to teach only the subject matter all teachers know, and to claim that these knowledges are prerequisite, hierarchical essentials for the complex learnings and fullness of education. Much of the public has bought that. And it has helped establish the myth that such indicators of achievement as SAT and National Assessment also indicate the quality of education occurring in the Nation.

I know that Roy Forbes joins me in wishing that test score means were not given such credence as indicators of educational effectiveness. But the practice is common even among education leaders. Patricia Sheil indicated that Houston pays teachers incrementally on the basis of achievement test gain scores. Many in the audience nodded appreciatively. Others of us cringed. The various tests are reasonable correlates of certain learnings, but they make a most unfortunate, incorrect announcement as to what is most important to learn and to teach.

We don't know what youngsters will need in their lives. We don't know what demands the future will make. We have to rely on our best guesses of course, but we also should rely on the intuitions of teachers and the intuitions of youngsters. We have survived as creatures on this earth largely because of our intuitions, and we should continue to help the coming generations rely on theirs. Our tests announce that the objectives identified by the authorities are much more important than the interests and curiosities of individuals. The question is not so much "do the tests tell us who is achieving?" but, "do the tests tell us what is worth learning?" Jim Wilson alluded to the obstacles to learning caused by testing. Allow me if you will to present a tiny bit of data. In an ongoing study in a large school district we have repeatedly asked teachers and students the following item.

How much have each of the following interfered with youngsters getting a good education in your district?

| | A lot | A little bit | Not at all |
|---|---|---|---|
| Racial discrimination | | | |
| Sex discrimination | | | |
| Bilingualism | | | |
| Overemphasis on testing | | | |

Overemphasis on testing was seen as much the greater obstacle with over half the teachers and students indicating it as at least a little bit an interference. I raise this issue because I believe the vision of teaching and education for the future has to be based on a realization of the fundamental conflict between control and educational competence. A great deal of syllabus-building in the 1970's (it could have been called school-based curriculum development in many places) was oriented to giving the teacher greater control in the classroom, giving the district greater articulation and standardization, and making officials at Federal, State, and local levels, and university consultants, appear to be doing something to improve education. Getting the schools to be more businesslike, more accountable, has occurred, but restrictions on the teacher thus have increased enormously with diminished opportunities to deal with the insights and imaginations and cognitive development of individual students.

On the MacNeil-Lehrer show last night, Secretary Bell said we have been preoccupied by attention to equal educational opportunity. I agree that that has interfered with good science and mathematics teaching. I disagree with his implication that it wasn't as important to increase access to good education as we made it. But we were all too single-minded about assuring access. We failed to look for other ways than busing and mainstreaming for providing access, and generated great numbers of classes in which the students rejected the teacher and the syllabus. Part of upgrading the job of teaching involves giving the teacher students who will commit themselves to learning and who will resist efforts of other students to sabotage the instruction. With NIE backing, several of my colleagues evaluated Jesse Jackson's Push to Excellence program. As a coordinated program it was ineffective in most schools, but as an ethic, as a movement, as an analysis of American education it was sound. Jackson said that education requires work and that the responsibility for committing students to work is not the school's responsibility or teacher's responsibility but that of the parents, and the students, and the neighborhood.

As part of the upgraded role of teacher, the teacher should have some rights of selection of students, at least on the basis of willingness to work, and rights to expel from class those who do not. Our society must find some other place to "warehouse" unwilling workers than in the classroom where teaching is going on. Our society owes every person who wants it an education. Today that should include opportunity to learn from classmates interested in learning.

Obviously, one way of increasing the interest of students in classroom learning means giving them more responsibility for selecting what they will learn. And another is giving the teacher more responsibility in selecting options for the students to select. Common learning objectives and common standards of achievement across students would have to be diminished. The district and State would have to have less control. It is a fundamental issue of central control vs. effective education.

To some what I am talking about is a pipe dream--but it is far from impossible. It is apparent that this individual responsive way is how most parents teach their own children, how apprentices learn from masters, how Japanese children learn in the classroom Jack and Elizabeth Easley studied, and how on-the-job training occurs in business, industry, and graduate school. Individualization of student task and teacher task of course doesn't mean that standards are sacrificed--just common, prespecified standards.

But I have drifted away from the epistemological reasons for major change in the role of the teacher. The schools have lost their primacy as the deliverer of information and ordered knowledge. Television, travel, the workplace, the marketplace, the park systems, the libraries, Bonnie Van Dorn's museums, and other "linkages," including peer friendships, already provide more understanding of complex scientific and mathematical ideas than do the schools. The schools should be helped to do better, but most students can be expected to learn more and more away from the teacher. The information avalanche has barely begun.

What is most needed from teachers in this onrushing world is helping the student make the most of outside opportunities, and supplementing them with integrating and ordering assignments--reading, problemsolving, discussions, and projects related to out-of-school learning the student already has begun.

In our NSF science case studies, Jack Easley and our team found that post-Sputnik curriculum reform projects were rejected by many teachers who wanted to teach what they had mastered, what worked for them. And they should--but more on individual bases. Those teachers also insisted upon teaching students to behave; they felt obligated to socialize them. This should also be expected of future teachers. Free floating discussions are not the answer, and most teachers would reject that. Douglas Seager's ideas of teachers having their own science projects is consistent with this vision of teaching. Others such as Cremin and Stodolsky have written about this role for teachers, and Lynn Gray spoke of it just an hour ago. Twenty years ago Agricultural Extension found that many farmers knew more agricultural science than the Extension instructors, so it helped those instructors toward roles as education facilitators.

The essential ingredients of teacher role evolution here are:

1. orienting to individual learning, not class learning;
2. orienting to what students and teacher are already interested in;
3. orienting to out-of-school learning opportunities; and
4. orienting to the students willingness to work.

In tomorrow's high tech world, following these orientations, the teacher-as-curriculum-developer makes sense. The curriculum he or she seeks is individual--finding additional experiences, readings, and computings for each individual student.

Individual Educational Plans (IEP's), such as were dreamed of by the authors of PL 94-192, are needed, but they should remain flexible and largely unwritten, not allowed to become today's checklisted artifacts of competency-based learning. The teacher should be free to rely as much or as little on today's district guidelines and textbooks as he or she feels makes sense in terms of what is best for individual children and their parents.

We have agreed at this conference that science and mathematics teaching need to be upgraded in the face of a disbelieving public and a cultural blitzkrieg. Many speakers pointed out that increased pay, prestige, inservice training, and exchanges with industry are important goals. But even if successful, they would not accomplish a long term solution. I do not believe we have much control over our destiny, but we can get ready for some changes which will be forced on us. A sensitive and compromising adaptation to the new habitat is essential for the survival of the qualified teacher of mathematics and science.

Steve Davis, Head of Mathematics and Computer Science,
The North Carolina School of Science and Mathematics

Essentially, I think I come at this from a different view than some of you. I was trained as a research mathematician. Before I ever taught anyone in a high school or junior high school, I taught college students. Then I taught graduate students. And as most people who do that, I was dismayed at the quality of the graduate student at the typical university. I had gone from a very good university with an excellent graduate program to a good university where the graduate students were not nearly as good. I did not think I could make them into good graduate students, either. At that time I was very confused because I thought you were supposed to teach mathematics to make everyone a mathematician. I think that is one of our mistakes.

So then I got this tremendous privilege and fell into high school teaching. On the third day I noticed something. When you teach 5 times a day, your legs give out first--I had never been so tired in my whole life--and your voice starts to go. And then you sense, "My goodness, though, when you see them every day you see the progress." When you work with them closely, you can see that students learn in different ways.

At first, I taught like most college teachers, I lectured. I thought that my students had learned from the lecture. Now I know they did not learn from the lecture. They learned from doing the problems in the book; they learned from talking to their classmates.

What I would like to put in context here as quickly as I can is the following: Please do not focus on just the science and mathematics crisis. As a speaker said earlier yesterday, view it also as a time of opportunity. Why do I feel the opportunity is so great? Because there is a grassroots movement. I want to share with you the evidence and the symptoms of the movement.

First, we have microcomputers coming into classrooms with teachers getting very little to no preparation on how to use them. Yet, they are being placed quickly in the classroom because school administrators feel this is one way to deal with computer literacy.

Second, there are many studies addressing the modernization of the school curriculum. There is a grassroots movement that says, "We know the situation must change." I don't know if that existed at the time of Sputnik. Right now the teachers know there is a need for curriculum change and they are looking for guidance.

Yet, I get incredibly frustrated. I work with teachers who use the pocket calculator to balance their checkbooks, to compute their grades, and to make their answer keys. But, they will not let their students use the pocket calculator on any graded work. We have a real hurdle here, because the calculator is a tool that they are familiar with, that they use, and that they consider friendly.

On the other hand, the microcomputer that teachers are being advised to use is not friendly, and they do not know what it can do. That worries me a lot. These examples indicate there is definitely a need for instructional leadership.

Today there is also a problem with the teaching of mathematics. That is, we are confusing the product of mathematics with what mathematics is. I did not know the difference between the product of mathematics and what mathematics is until the second or third year of graduate school, and that concerns me. There ought to be some way that education department faculty and mathematics faculty could work together so that the mathematics courses are not just taught as though they are preparing mathematicians, and the education courses are not just taught as though these people will teach a wide variety of subjects. They ought to be able to integrate mathematics and teaching.

Not long ago, a colleague pointed out something to me that really got my attention. If a teacher wants to teach intuition, understanding, and the ability to be a learner for life, the teacher is open to attack, because someone will always ask, "Well, did the students learn this specific fact and did they learn that specific skill? Well, what did they do in your class?"

"Oh, but they learned mathematics and the beauty of it and what it is and how to solve problems." If you are not respected by your community, that line falls on deaf ears.

We need to raise the status of the profession so that teachers can do what they need to do and not just be teaching computation. The pocket calculator can be used to teach estimation and other kinds of cognitive skills, in addition to computation.

Technology has started this grassroots movement. When I say "technology," I am thinking of all sorts of things. Let us think in terms of video disks, teleconferencing, and the computer. Wait until you see the advances in teleconferencing, now that it's not regulated.

Today teacher-trainers have an additional burden. That is, teacher-trainers must become more knowledgeable than almost anyone else about the application of technology to instruction. They cannot respond to the task by offering training in how to use this piece of equipment or that piece of equipment because they cannot outguess technology. Among many tasks, teachers should help students learn what is really fundamental to technology, instruction, and communication so that no matter what the technological change is in the next 20 years, they will have a base from which to work.

My instincts tell me that the real future for improving schools is inservice training. Why? First, the teachers desire it. That is the grassroots movement. Second, I suspect a very high proportion of the teachers who are going to be teaching in 1990 are already in the classroom, so inservice training is necessary. Third, inservice training can be more responsive to local education needs.

I want to qualify my statements with the obvious observation that seems to escape those of us in education who are in a position to do inservice training. Actually, no one is now in a position to do it well because there is not enough money. In almost any other business, when people are involved with inservice training, they are trained and paid while on the job. Only in this profession do you do inservice where you pay the fee and you are not being paid while you do it. Something is very wrong there. It worries me a lot.

I want to make one more comment. I will use a metaphor, one I would not have thought of if Dr. Roy had not used his glue metaphor yesterday. My favorite metaphor is that of Peter Drucker's sailboat. Drucker is big in managerial science. He was assigned to look around and try to figure out what organizational structure guaranteed success for a company, and he discovered that all of these companies were different. Some were successful and some were not. He was trying to figure out what it was that made him successful, and he came up with the metaphor of the sailboat.

Most people look at a sailboat and think that the sails propel it--the equipment in the schools, the teacher training, the school room and facility itself, parental support, et cetera. But if you think about it, it is the invisible wind that propels the sailboat.

Right now I see us in a situation where we need some more sails. We need more equipment in the science labs. The micros are just coming in. But still the wind is going to be the key, and that must be the communication to the classroom teacher--that people care, that it will be backed up with action, and that it is going to start soon.

But whatever it is, let's do it right and not try to do 17 different things to find out which one works, because the race to improve schools, teachers, and students could be lost in the process.

Naama Sabar, Professor,
School of Education, Tel Aviv University, Israel

The title of this conference reminds me of a story placed in this country not so many years ago. It was at an international conference on computers which had a contest to provide a very new kind of software for a very simple message. The message was, "Why is there a shortage in meat?"

When the organizers asked the participants what questions there were before the contest started, the Poles raised their hands and said, "What does it mean, 'meat'?"

The next question came from the Russians, who asked, "What does it mean, 'why'?"

And the last question was from the Americans, who asked, "What does it mean, 'shortage'?"

That was not too many years ago. I am afraid these times are over.

First of all, I wish to thank the organizers for inviting me to such a stimulating conference, with a unique array of participants. I am particularly honored to be here because to me it looks almost like the list of "Who is Who in Science and Mathematics Education."

I accept the advantage of being the last synthesizer and probably the only foreigner in this audience, and I want to thank the organizers for the very well-thought-out preparation of this conference, expressed in the wide representation here of the different fields that should be involved in analyzing such an issue.

The papers presented were so thoroughly prepared, with clear messages and relevant updated information. When you see the proceedings, you will know how many 1982-1983 references were included. These data were regarding the common myth versus realities in relevant research.

I also think special credit should be given to the diverse approaches that we have heard regarding alternatives that are presently taking place successfully in our system.

Being a woman, a minority, I would also like to congratulate the organizers for the even distribution that was given to contributors between the different ethnic groups and the genders. I take it for granted, even in a profession that is so heavily female, that much of the decision making power is still male.

Lastly, I would like to give special thanks to the discussion moderator who led the contributing discussions so elegantly and so well.

Now I would like to share with you some of the thoughts, observations, and questions that came to my mind while listening throughout these 2 days. Most of these thoughts have been heard in the past 2 days, but I would like to make my own supplement and perhaps rephrase--and it may sound even amplified to be heard from an outsider.

I must admit I feel like the boy in "The Emperor's New Clothes" coming after these two preceding synthesizers with their high-powered questions. I might post some very simple questions, such as: How is it that a country that in most fields of science and technology competes so successfully with all countries in the free world, due to your wealth of ideas, quality of manpower, natural resources, and facilities, has reached this present crisis in the area of teaching, exemplified here in science and mathematics education?

Well, I think that you all know part of the reason. This society is not ready to give now what it takes to build and maintain a quality education system. In saying maintain, I also refer to the implementation system that has been mentioned in this last afternoon's session.

Does anybody really think we can carry out even a few of the wonderful ideas that have been expressed here without budgets? Good will and missionary complex, a new term for me, are not enough to get good teachers to do the job. Teaching positions offer neither status nor considerable financial compensation, and teachers are human beings with purchasing needs.

It may be exciting for a young student to follow his or her interest in young children and the nurture of knowledge in kids and take a teaching position. But then when he or she plans to build a family, their priorities will definitely change. Or do we say that teaching can only be suitable for second breadwinners?

By the way, I really wonder how many teachers can purchase an Apple--and I don't mean the fruit, I mean the computer--when so many microcomputers are to be found now in their students' homes.

I think it would be fair to say perhaps that among the myths in circulation is the one that says we cannot get any more dollars into the system, yet the reality is that if we can, it will make a difference.

The exodus of good young science and mathematics teachers into industry that we have heard described so well by Betty Vetter is a clear sign of that. What do we really expect of science and technology teachers? As I see it, they are expected to be subject-matter specialists in an area where changes are the fastest in comparison to all other subjects taught in school. We expect them to compete with high quality super-power educational programs that are now offered commercially by private industry.

We also expect them to be very intelligent, broadminded people, with a very clear set of values, to be able to bring into the classroom such topics as the relevance of science to social problems. And those relations and concerns are increasing in numbers on a day-to-day basis.

But in addition to all of these--and I skip the expectations in manipulating skills, operating a lab, and so forth--we also expect the science and technology teacher to be a topnotch educator and pedagogue and to handle a great number of problems that the whole of society faces, topics like those Lee has already mentioned: smoking, alcoholism, drugs, sex education, and whatnot. And does the teacher really get recognition for this complex task?

Why is it that an exceptional scientist--and very likely one of these science teachers had to do with his successful career--may win a Nobel Prize? An exceptional writer can stand for a Pulitzer Award. Even a stage decorator can be a candidate for a Tony Award. Yet, the only recognition an exceptional teacher will get is recognition from his own association. The local Rotary Club may acknowledge him as well.

An automobile repairman makes money. A competent scientist, at least in my country, has status. An American physician has both money and status. A teacher here has neither.

Well, out of this gloomy picture I think one good thing is emerging. There is a tremendously heightened awareness of the price to be paid to improve science and mathematics.

So we do have the momentum now. We just need to do everything we can to accelerate that momentum, and it is up to the people here to transmit the very carefully thought-out recommendations that have been heard here to the people in power--to make things work so that in 5 years, probably through computers, we will not be crying over a deeper crisis but rather discussing further advances in prospect.

I endorse most of the recommendations that have been made and won't repeat them now. But I would like to add to the other explicitly mentioned research need that research tools should perhaps be used--supplementary ones--other than the regular statistical measures. I know the movement is very strong, but I just want to make that point.

There were recommendations about developing opportunities for teacher promotion in school, developing a career ladder for all teaching areas based on excellence. And under this heading I recommend that several prestigious institutions cooperate in establishing an award, including a generous cash award, that would probably be donated by industry and that would be addressed to the reward of excellent teaching on an annual basis.

I have heard some recommendations regarding the importance of elementary science and mathematics education with respect to future choices students make in these areas. I strongly recommend that you invest more in improvements of science and mathematics teaching as early as possible, even in pregrade school. It has been tried successfully in my country. Since we now know the enormous capacity of young children to learn and their natural curiosity, I believe that it is a very promising field for the investment.

A number of contributors suggested that we look at other industrial countries and change our requirements accordingly. On this issue my recommendation is, "Slowly, please." An engineer from the U.S.S.R. will not qualify in this country, nor will a medical physician. A Japanese engineer will qualify. Yet we cannot expect of our education system what we can expect of the Japanese. We don't give the same respect to our teachers that they give. Nor do we give the salaries or provide the outstanding facilities that the Germans give to their teachers.

I would also encourage industries to compete with each other in publicizing how much they give to education relative to their total budgets. Maybe it should become a slogan with advertising, "We are better because we care. We give more to schools."

That leads me to my one-before-my-last point, and that is an urgent need for improvement of your public relations skills when it has to do with your schools.

Anne Flowers in her paper quoted Cremin, that we are providing a remarkably successful education program to the general population, and I think that is not well enough known. Why don't you inform the public that in spite of all these difficulties, there are outstanding things going on in your schools?

I can tell you again as an outsider, do you know you have a remarkable system of libraries--even in the very small schools--outstanding curriculum centers? I could go on and on and on. Yet you would benefit greatly if only a little of your vigorous salesmanship and marketing skills could be applied to your schools.

Last but not least, just as a civilized country should be judged by the place it provides for its elders, and not for its football players, I firmly believe that a country should also be judged by the priority it allocates for education, meaning per capita expenditure on education. In that respect, I must give full credit to my own country, where education comes second only to security.

Perhaps the United States Government should locate education as part of its defense and security in order to maintain its excellence and the leading position which it so thoroughly deserves in our present world.

# SUMMARY AND DIRECTIONS FOR ACTION

Thomas L. Good
Gail M. Hinkel
University of Missouri-Columbia

The summary of conference papers and discussion does not provide a clear mandate for action to resolve the teacher shortage and general literacy problem (teachers, citizens, students) in mathematics and science. Certainly there were important and healthy differences among participants in how they define the problems and in the steps they believe are most likely to solve the difficulties. The conference provided a broader understanding of the problems, identified several points which need resolution (and which call for basic research and development activities), and produced examples of what some agencies, school districts, and universities are doing in response to the teacher shortage and the literacy problems. The information, ideas, and problems identified at the conference will be of value to school systems as they deal with these issues and to decision makers who face difficult but important policy challenges.

As we write this document in early March, several States are passing legislation that addresses certain aspects of the problem (e.g., higher curriculum standards). The Congress of the United States is now deliberating legislation that will provide badly needed funds that can be used to help correct deficiencies in these areas.

Considering the rapidly growing public concern over these issues and the money that Congress will soon make available, we believe it is likely that the money appropriated will be poorly spent in most instances. Although the funding will probably be inadequate, careful thought before these funds are spent will (or would) have more significant, long-term effects than quick spending will achieve. We acknowledge that there is an acute shortage of mathematics and science teachers, and particularly of well-qualified teachers. The problem is enormous and important and the continued economic productivity of the United States depends upon a successful, long-term response to the shortage and the related problem of scientific and mathematical literacy. Clearly, some action must be taken immediately; however, we believe that certain aspects of the shortage can best be solved by discussion and basic research rather than by quick spending and radical changes in the curriculum that are based primarily on short-term reaction or impulse.

What, then, are the issues that the participants at this conference believe should be studied? In response to this question, we will discuss topics upon which there was reasonable consensus among participants and general problems which cannot be adequately solved by individual States or school districts. We view three broad areas as meriting attention: curriculum reform, process research on classroom learning and instruction, and increasing public support (which involves altering salaries, the status, and duties of the profession) of classroom teachers.

## Curriculum Reform

The most prevalent view expressed at the conference about the current status of mathematics and science education was that 95 percent of our students (and citizens) need better mathematics and science training, not the top 5 percent. Participants generally agreed that the present curriculum was producing an adequate number of advanced scientists and that our supply of exceptionally talented students is not in jeopardy. Still, most of the programs described at the conference were designed to identify and to educate gifted and/or minority youth. This is of course understandable (and we need such programs), but it is regrettable that more attention has not been placed upon improving the mathematics/science curriculum for the average student. The most important issue concerns what can be done to prepare citizens who understand and are therefore capable of using technology in intelligent and appropriate ways and thus of making informed decisions about technologically-related issues. The answers to this question were varied and complex, but the most frequent response was the call for a more appropriate, relevant curriculum and for qualified teachers to implement and expand it (we will return to the teacher issue later).

Beyond the frequently stated opinion that curriculum reform was needed, there was little agreement as to what direction this reform should take (readers who wish to scientifically conduct their own content analyses of conference proceedings should review this massive report...we encourage replication efforts). In part, this is because the conference was organized primarily as a problem stating group and hence, little time was spent discussing the new curriculum. Because of declining test scores and student interest, dissatisfaction with many science and mathematics textbooks, etc., there is societal consensus that curriculum reform is needed. But poor performances on assessment instruments do not tell us what abilities should be measured or how to correct identified problems.

To many citizens and educators, curriculum reform means more courses and indeed many States have passed legislation which requires that students take more courses in mathematics and science. However, considering that many students develop a distaste for science in elementary school, mandating more coursework without seriously studying the quality of science and mathematics curricula, particularly in the early grades, may exacerbate the problem.

Although most papers at the conference addressed the problems of mathematics and science education in secondary schools, we believe that if secondary science education is to be improved, it will be necessary to simultaneously increase both the quantity and quality of science education at the elementary level. Studies by Ebmeier and Ziomek (1983) and Stake and Easley (1978) indicate that most elementary pupils receive little or no instruction in science. In a study of 75 teachers in grades 2-6, Ebmeier and Ziomek found that an average of only 15 minutes <u>per week</u> was spent on science in second grade classes. By fifth grade, this time had only increased to 43 minutes. Furthermore, the time spent on science in most classes was considerably lower than what the district recommended.

Still, we need further descriptive data on which to base curriculum reform efforts. Until we have such information, it is hard to know how much time should be taken from other curricula areas and devoted to science. Schools have many subjects of limited value (especially secondary schools), and curriculum reform in mathematics and science must involve an examination of the total curriculum by mathematicians and scientists, teacher educators, and classroom teachers to determine how the curriculum should be altered.

Scientific knowledge is presently growing at a rapid pace and it appears that many technological advances will be made in the next few years. If the United States hopes to prepare its citizens to live in a world heavily influenced by technology, educators must determine what scientific information and processes students should know. What do we mean by a "technologically literate" citizen? Although there is no simple answer to such a question, we believe that it is imperative that the current curriculum be described and serious scholarship conducted to determine how it should be modified.

Although we acknowledge that the curriculum needs reform, we are not certain what the nature of that reform should be. In fact, it will be impossible to make useful changes unless there is a clear understanding of what the curriculum is and should be. We therefore urge that at least some appropriated funds be spent in 1983-84 for commissioned work designed to identify possible areas of reform and ways to achieve improvements. What do we want students to be doing in classrooms in 1993? What are the criteria that we will use in 1993 to determine whether or not the money and time expended in the past ten years have substantially improved technological literacy? Serious study of these goals in advance might make it more likely that curriculum reform efforts will be at least moderately successful.

Some excellent study of curriculum reform has been made. For example, the National Council of Teachers of Mathematics has produced a useful, comprehensive statement outlining the mathematics curriculum needed in the 1980's. This report strongly advocates more attention to problem solving but does not define problem solving at a functional level. Funds invested in carefully designed conferences, research studies, and development activities might yield criteria that could be used to construct and to evaluate curricula. With criteria and a broader understanding of what is meant by problem solving (and other terms such as "scientific literacy") we could begin to answer a variety of practical and important questions such as the following: How do we operationally define problem solving? How do we differentiate appropriate problem-solving teaching from inappropriate or poor instruction? What percent of our teachers attempt to teach problem solving? How do teachers' definitions of problem solving compare to those called for in curriculum reform efforts? How do teachers whose definitions of problem solving correspond with those advocated in the curriculum reform teach (or structure their classes) problem solving? What is appropriate and inappropriate about present curriculum experiences for students?

Funds invested in development designed to clarify intended curriculum reform could use new technology (as well as decribe it). For example, competent teachers who include problem-solving instruction in their curricula could be identified and videotaped and these tapes could be shown to other teachers to demonstrate techniques and activities which characterize effective problem-solving instruction. We therefore believe that if classroom teachers, educators, and scientists are given sufficient funds it would be possible to identify and develop more appropriate curricula and to demonstrate them more effectively than the rapid innovation that has characterized past change in American curricula allows. As any student of educational history realizes, attempts to clarify terms involved in curriculum reform efforts (discovery learning, open education, process science, new mathematics) have traditionally come only after a reform has been tried and subsequent evaluative data are negative or uninterpretable. If conceptual clarity were achieved and implementation measures constructed, it would be possible for empirical research conducted in 1984 and 1985 to determine whether new curricula had positively affected students' skills and interest in science and mathematics.

Although we do not advocate a national curriculum, we do believe that the delineation of key curriculum and instructional terms is important. For example, there are many questions concerning instruction about an important mathematics concept like "variable:" When should it be introduced in the curriculum? What should follow? These are issues that individual school districts cannot adequately resolve with existing budgets and personnel.

In essence, each day in American classrooms, thousands of informal "field experiments" occur when teachers use their own approaches to present various concepts or principles contained in school curricula. There is growing evidence some teachers cannot improve upon the poor quality of text materials (because of inadequate backgrounds in science and mathematics) and thus distort the concepts they intend to teach, so that many students' misunderstandings of some concepts are not corrected, despite instruction. Furthermore, research on instruction in specific scientific concepts in 14 fifth-grade classes (Eaton, Anderson, and Smith, in press) demonstrates that many students bring to the classroom misconceptions about scientific concepts such as light and vision. In this study, some misconceptions were reinforced by the textbook and the accompanying teacher's guide. It is therefore not surprising that even after 6 weeks of instruction, three-fourths of the students studied still held basic misconceptions about these concepts (see Brophy, 1982 for a detailed discussion of teacher distortion of intended instruction and dependence on textbook materials).

Because many teachers do rely heavily on textbooks and teachers' guides for instruction, any attempt at reform of curriculum and instruction must necessarily include a careful examination of textbooks. Freeman, Kuhs, Porter, Floden, Schmidt, and Schwille (in press) suggest that the textbook a teacher uses largely determines the curriculum students receive. However, these investigators found that the mathematics curricula presented in four textbook series which dominate the market vary considerably. They also found considerable differences between the content of various textbook series and that measured by some standardized mathematics achievement tests.

One recent criticism of the science curriculum is that it is passive, that students learn the knowledge of science (facts, concepts, findings...generated by others) but have little opportunity to engage in the process of science. Telling such teachers to include more science process and less content in their curricula is as likely to add to the problem as to correct it. Such a recommendation would be variously interpreted and implemented. In addition to study to provide a purpose and direction to general curriculum reform, we need research and development that will help teachers understand major scientific concepts and learn alternative ways in which such concepts can be taught (to determine how the general goals of curriculum reform could be implemented in specific instances).

Although there is evidence that effective instruction can make important differences in how much students learn and retain, most of this research has not examined the learning of specific and subject matter concepts in particular contexts. Some funds should be designated for identifying important curriculum concepts, devising interesting ways to present those concepts and/or to allow students to discover them. Such work could be completed at a national level by teams composed of teachers, educators, and scientists. Ultimately, the value of such work should be tested by empirical research.

We suggest that teachers would benefit from viewing videotapes of competent, talented teachers conducting classroom activities related to key concepts or issues (variable, quantam theory, place value, equivalent fractions). Although it would be impossible to film instruction in many concepts (at least initially), it seems important to assemble video libraries that illustrate the process or problem-solving skills called for in relation to particular concepts as well as to the areas of science and mathematics generally. Carefully selected video lessons would be an improvement over most classroom observation, and videotapes could be supplemented by discussion of salient aspects of teaching situations. The potential is especially great in science, where time lapse photography and other techniques can allow students to observe the efforts of an intervention or to see change occurring over time periods, and thus to get the benefits of an experiment, when actually doing one experiment in the class might be too expensive or time consuming, or otherwise unfeasible. A variety of technological advances have occurred in the past decade, but teaching has been largely unaffected by them. Such development work is cheap and relatively straightforward, and it is therefore surprising that so little has taken place.

Ultimately, such work might lead to a better understanding of issues such as productive strategies teachers can use, problems or misunderstandings students are likely to develop when attempting to learn concepts, how these misconceptions can be detected, and what specific strategies teachers can use to help students with particular misunderstandings. Such basic information could vastly improve elementary and secondary education in this country. Some research in this area has been completed (see Brophy, 1982), but it has not been organized around important subject matter concepts.

## Simulation/Curriculum Development

Considering that technology can also make complex phenomena concrete and accessible to students, one wonders why more first-rate simulations and videos illustrating scientific processes are not available. For example, some of the complex time/motion concepts in physics are easy to depict on video. Videotapes of important experiments in science would do much to allow students to see scientific data being collected and to witness the process of knowledge being accumulated over time until it has practical consequences. Appropriate, selective use of a few demonstrations of the scientific process could help students to develop a respect for the need to measure carefully, to change perceptions as data accumulate, etc. Naturally, videotapes would not be a substitute for students' actual conduction of, or involvement with, science experiments.

Although curriculum goals are affected by local needs and preferences, the cost of producing exemplary scientific videos and simulation activities is so high that few school districts could afford to develop them. However, once produced at the national level, they would be valuable resources for many school districts.

Several participants at the conference suggested that few students actually apply the principles of science before they pursue advanced degrees. Legislation presently being acted upon in Congress involves expenditures for the purchase of new scientific equipment as well as the repair of existing laboratories. Students undoubtedly need laboratories if they are to practice science; however, many teachers will need training in order to use new equipment.

Improving curricula and bringing technology into schools where teachers are not prepared to use them will create massive training needs which will require attention and funds. For example, local districts will need help in acquiring, maintaining, and using new equipment appropriately. National research and development activities should be conducted to help local school districts evaluate their success in training inservice teachers to use new curricula and equipment.

Teacher Education

If the public school curriculum is to be improved, then careful attention must be paid to the teacher education curriculum and funds need to be invested (as Lanier and Porter suggested) to study the relationship between knowledge of mathematics and science and classroom teaching. We need to know the content of teacher education programs if such programs are to be evaluated and improved. Unfortunately, we have a paucity of reliable information about how teacher education programs affect teachers' beliefs, knowledge, and skills and how short-term training influences long-term teaching performance.

Although some teacher education programs are helping teachers learn about and utilize technology (computers, video simulation, etc.), we suspect that many are not. Teacher education institutions face complex decisions as they attempt to allocate scarce resources. For example, they must decide whether teachers should be familiar with computer simulations or be able to design simulations. That is, should teachers merely know where to obtain computer software or should they know how to improve inadequate software themselves?

Another important issue which teacher education institutions must address concerns whether elementary teachers should be trained as generalists (as most currently are) or as specialists. In order to possess a thorough knowledge of subject matter in any area, multiple, diverse curriculum materials and relevant instructional techniques, elementary teachers may need to be trained as specialists. Such training may be especially necessary for effectively teaching a subject such as science, where new information and developments occur rapidly.

It seems to us that some Federal support and subsequent research (guided by agencies like the National Institute of Education and the National Science Foundation) could help to indicate in more detail how scarce resources can be used advantageously in teacher education programs. It would be pointless and wasteful for each school district to develop its own curricula and programs for improving the technologically-related skills of teachers and students.

Classroom Research

Clarification of curriculum goals in mathematics and science should make possible focused but comprehensive research on instruction in important topics in mathematics and science. To obtain curriculum goals, however, it will be necessary to conduct basic research on classroom processes related to these goals. In this section we will describe an important but neglected curriculum area in mathematics, problem solving. This discussion illustrates why research is desirable if improvements are to be made in classroom instruction and in learning.

In a recent examination of much of the mathematics education literature, we found many statements concerning how problem solving should be taught; however, we found no careful analyses of classroom instruction in problem solving. There are critiques of textbooks and critical and insightful examinations of student performance. Indeed, some of the research illustrating that students can answer mathematical problems correctly without understanding them is quite important and intriguing. Still, it is curious that nowhere in the literature can we find statements describing what takes place when teachers teach problem solving. How do classroom teachers define problem solving and how do they attempt to teach it? How much time is spent on problem solving? At present, there are no dependable data with which to answer such questions. It seems to us that if one wants to improve the mathematical problem-solving ability of students in American classrooms, these questions must be answered.

Thus, mathematics educators should conduct observational studies of classrooms during instruction in problem solving, particularly in classrooms of teachers who are especially adept at teaching problem solving. There are both theoretical, conceptual, and empirical reasons for conducting such studies. Polya (1966) notes that solving problems is very much a practical art and, like swimming or playing the piano, it can be learned only by imitation and practice. He suggests that in order to become a problem solver, one has to solve problems. He points out that one of the ways students can become more skilled at problem solving is by having active teachers who can demonstrate the process by formulating choices carefully and can illustrate ways in which to deal with proposed problems. We realize that there are many alternative ways to characterize problem solving; however, Polya's emphasis is plausible and provides a rationale for examining ongoing classroom instruction.

Similarly, it appears that students are deficient in other important mathematical skills. Such "problems" can also be remedied through careful observation and experimentation (for some recent work on estimation skills, see Reys and Bestgen, 1981).

There is ample documentation from the mid 1970's and early 1980's that we can gain valuable information by studying competent teachers. Several extensive research programs funded by the National Institute of Education provide observational evidence that teachers vary in how they think, act, and use time in the classroom. Furthermore, these variations among teachers have been related to student achievement in several field experiments (see Gage, 1983; Brophy, 1979, 1983; and Good, Grouws, and Ebmeier, 1983).

We know considerably more about classroom teaching than we did a decade ago. In 1973, our information about the effects of classroom conditions on student achievement was weak and contradictory. In the ensuing ten years research (much of it influenced by funds and coordination from the National Institute of Education) on basic skill instruction, especially in reading and mathematics, has moved from a state of confusion to a point where several successful experiments have been conducted. These studies, in contrast to less sophisticated and often methodologically flawed research that took place in the past, illustrate that teacher behavior can significantly affect student achievement.

Furthermore, there is evidence that the skills effective teachers use can be taught to other teachers. In building a program of <u>active mathematics teaching</u>, Good and Grouws (1979) began by <u>observing</u> how more and less effective teachers (using student performance as the operational definition of effectiveness) taught. We combined this information with other research in order to build a teaching program that could be tested in intact classrooms. Findings showed that the program had a positive impact on student learning and that most teachers could implement the program without much difficulty. We felt that too much mathematics work in elementary schools involves a brief teacher presentation and a long period of seatwork. Such brief explanations before seatwork do not allow for meaningful and successful practice of concepts that have been taught; and the conditions necessary for students to discover or use principles on their own are also lacking. The program helped some teachers to overcome these problems.

The argument here is that much can be learned from the serious study of practice. As Flowers, Lanier, and Kelly noted, many myths about educational practice exist, in part because we possess few data with which to describe practice. What data we do have indicate that teaching practice is much more varied than most people currently believe and hence, simple, generalized recommendations (e.g., increase time on task) will do more harm than good. Some participants at this conference suggested that teachers need to talk less and let students do more science. However, in many classrooms, teachers hardly talk at all and students are left to complete dismal "science" worksheets. In such classrooms, teachers should talk more (about the meaning of science; the concepts being studied) and students do not need to do more science, but a different science. Curriculum reform without descriptive research is, in our opinion, self-defeating.

Although much recent research examines basic skill instruction, there is reason to believe that other processes could be effectively studied by the observation-development-field experiment research approach described above If goals of curriculum reform and key concepts are identified, research could be directed at these areas.

The focus of such future work should not be limited to teachers. A similar observational model for understanding mathematics learning has been used by Krutetskii (1976) to study how excellent students attempt to learn mathematics. Also, as noted earlier, a growing number of researchers are interested in student behavior (e.g., time on task) and perceptions (Do they view problem-solving assignments as a challenge?), and such work can help to make instruction more effective (see for example, Peterson and Swing, 1982; Weinstein, 1983).

Many strategies for promoting effective learning are not common aspects of classroom practice and thus the study of practice is not the only way to bring about desirable change. For example, Rosenshine (1983) demonstrates that successful school programs can be achieved through systematic thinking and development independent of sustained observation of teachers.

Our purpose here is not to identify research areas, questions, or paradigms that merit support. We do wish to suggest a general direction which we believe some future research should take.

Past research has been aimed at the curriculum, <u>or</u> teachers, <u>or</u> students. As we stated earlier, if research is to be effective, its context must be focused. However, within the particulars of a given research study (e.g., middle school science classes), and <u>subject matter</u> issues that are being studied as well as how <u>teachers</u> and <u>students</u> think and behave when they study particular concepts. Furthermore, curriculum research tends to examine content, sequence, and pace issues and to ignore what teachers and students do when they actually <u>study</u> curriculum.

We also believe that teachers and students need better science textbooks and teachers need manuals to help them understand the concepts and processes they teach. Without better materials and better illustrations of effective teaching/learning environments, students' scientific literacy will not improve.

More complete theories of instruction in mathematics and science (and of instruction generally) must also be developed. Lee Shulman suggested at this conference that there should be more structure to classroom instruction, and that students' understanding and knowledge of a subject should accumulate and develop over time. According to Shulman, the last short story taught in an English class or the last unit in an algebra course should be taught/learned somewhat differently than the first material, because students hopefully have learned concepts, principles, and procedures for analyzing stories and problems. However, we have no instructional theories which enable us to examine these issues and little extant empirical data upon which to build such theories. As Bruner (1966) noted, a theory of instruction needs to describe the ways in which knowledge and concepts can be effectively sequenced so that students' understanding of instruction is enhanced.

## Recognition of Teachers

In a variety of ways conference participants expressed their belief that teachers need more pay, recognition, public support, and better working conditions. We agree. Many teachers have difficult jobs, are poorly paid, and are frequently the targets of societal criticism. However, we must recognize that there is variation among teachers. Unfortunately, educators, researchers, the public, and even teachers suggest that most teachers behave alike and have similar effects (whether positive or negative) on students. For example, some conference participants suggested that teachers are not capable of modeling problem-solving strategies, and other researchers indicated that most teachers teach mathematics in the same unproductive fashion. Others suggested that the study of teacher behavior has been unproductive and recommend that research address other areas. We submit that these generalizations about teachers and teaching often result from the failure to recognize variations in teaching performance. In reality, some teachers are worthy of emulation and others are not; some offer exciting, productive classrooms and others' classrooms are poorly organized and taught, and little productive learning occurs.

Because of society's failure to recognize and to reward satisfactorily competent teachers, many teachers (particularly the best ones) have left teaching. They do not want to work at an occupation that has low pay, little intellectual stimulation, and little opportunity for advancement. As Wimpelberg and King (1983) state, "To endure the conditions accompanying life as a teacher, the person must have elaborate support systems, unusually high commitment to the roles and tasks of the job, or—on the negative side—no real occupational alternatives." Many conference participants pointed out that teacher salaries (especially those of experienced teachers) are too low and that teachers continue to obtain salary increments that are considerably less than those of other white-collar workers. There appears to be widespread and growing dissatisfaction among teachers with their pay and professional status.

Schlechty and Vance (1983) present data which indicate that too many of the most effective teachers are leaving the profession and that many students with higher aptitudes no longer enter teacher education programs. Despite evidence that the pool of bright students seeking enrollment in teacher education programs is declining, some teacher education programs still attract qualified candidates. For example, at the University of Missouri, students who enter the teacher education program rank at the 70th percentile of their high school classes (this figure has remained stable for 10 years).

Though we face a serious problem at present, it is still a solvable one. However, after another two to five years of neglect (particularly of the salary issue) and the loss of a higher percentage of capable teachers, the situation may become unmanageable. Because of a decline in the overall quality of teachers, it is more difficult for an individual teacher to be effective. Furthermore, because of increased public concern over the performance of public schools, there is a growing unwillingness to fund public education.

There is much that can and should be corrected in many teacher education programs and in public schools. Besides increased pay, there are other ways in which teachers can be compensated. For example, more documentation of teachers' preferences concerning the conditions and professional duties associated with teaching would be useful. Among the many options that could be used to improve teaching conditions: summer employment opportunities in business or industry; reducing record keeping and other clerical duties; three to four hours a week during the school day for planning; release time to observe other teachers, discuss instructional strategies, and view classroom films with other teachers; the chance to specialize (Why should elementary school teachers be asked to be knowledgeable in several subjects?); helping educators and researchers to develop curricula; free college tuition for computer and science classes; more involvement by college and business personnel in actual classroom instruction; and preparation of learning aids. Although most current legislation is intended to encourage persons to become mathematics and science teachers, the conditions of teaching must be altered so it becomes a more challenging, interesting occupation. We are especially encouraged by proposals that advocate bringing non-teachers to the classroom to share knowledge and expertise.

In the final section of the paper, we would like to di[illegible]ss a salary plan that has received considerable attention, and the possibi[illegible] of national study and development to help guide local school districts in devising salary plans and allocating resources.

Master Teacher

We have suggested many ways in which teaching can be made more attractive and prestigious: serious study of teachers; the sharing of teachers' successes with the public; raising salaries; improving working conditions; and altering teachers' duties (role). Yet another way to improve teachers' morale and classroom performance, and thus to attract more talented persons to teaching, is to identify and reward exceptional teachers.

Teachers who achieve excellence in classroom instruction, curriculum development, and supervision and training of other teachers should be identified and rewarded. Unfortunately, teachers who have taught for seven to ten years and who have similar training receive similar compensation, irrespective of whether they work 35 hours a week and perform dismally in the classroom or work 75 hours a week and perform superbly. The reward structure of teaching is flat (unstaged) and salaries are usually based on years of classroom teaching and the number of post-graduate courses completed. There is ittle opportunity for advancement, and most teachers reach the apex of the salary schedule in about 15 years. At the conference, Terrel Bell, Secretary of the Department of Education, also advocated increased pay for master teachers.

However, the potential advantages of a Master Teac[illegible] plan are not assured, and all incentive plans have problems. Participants at this conference argued that the problem facing American schools was a decline in general teacher morale and that this problem needs attention if the teacher shortage in mathematics and science is to be remedied. The present pay of average teachers is much too low, and if funds for master teachers' salary increases come at the expense of upgrading teachers' salaries generally (a common teacher objection to this plan), general teacher morale is likely to be negatively affected. However, most differential pay plans proposed to date require that funds be added to educational budgets; money is not being taken from some teachers pay others. To the extent that funds for master teachers are part of a p. to increase the salaries of all teachers (at least to some degree), this is an encouraging strategy to explore.

Others argue that decisions about who should be designated master teachers will cause dissension among teachers. First, many teachers believe they are outstanding teachers and will be disappointed when not selected as master teachers. Furthermore, some fear that the criteria for selection will relate more to political savvy than to teaching skill or subject matter knowledge. However, the obvious fact that reliable criteria will be difficult to establish does not mean that we should not try to define levels or stages of professional advancement in teaching. We must be certain, though, to define the criteria carefully, revise and review such criteria periodically, and seriously study related issues (who sets the criteria, how judgments are actually made) if such plans are to work.

While rewards for teachers are important, a large measure of the value of such a plan lies in the discussion it encourages about what constitutes excellence in teaching as citizens, public officials, teachers, and teacher educators debate this issue. A focus on excellence in teaching would help to identify positive aspects of schooling and enable the public to become more aware of the complexities of teaching. An increased public awareness might lead to greater gains for all teachers (i.e., an increased public willingness to fund higher salaries). Further, master teache[illegible] plans could add to our knowledge of classroom practice and increase our [illegible]acity to illustrate to other teachers strategies that are particularly [illegible]esting or effective. For example, master teachers could use videotapes of [illegible] classroom performance, curriculum units they have developed, or student[illegible] products in order to assist in the training of other teachers.

We suspect that master teacher plans will have more effects in some school districts than in others and that in too many cases funds will be spent in ways that will not encourage or reward competent teachers. Many plans address the improvement of teaching generally and the need for master teachers (see for example, Schlechty and Vance, 1983). However, an immediate attempt to identify and examine issues and problems associated with the implementation of master teacher plans and alternative ways of responding to these problems would involve money well spent to provide important technical and conceptual support to local school districts. Although local districts need to identify and to reward those school processes and products that they value, it seems a waste to require every school district to address a number of sophisticated technical questions that require the attention of economists, psychologists (How much money is necessary for real incentive?), sociologists (How can the potentially divisive effects of competition be minimized? How should career ladders be structured?), as well as classroom researchers, subject matter specialists, and measurement specialists. If the plan is to work, serious conceptual study must occur. It will probably be necessary to define several stages in the teaching career ladder (each involving extra compensation) toward the final status of a master teacher. At each stage teachers' professional duties could expand to include curriculum development, assisting with research, and supervision and training of other teachers.

## Conclusion

The shortage of qualified mmathematics and science teachers is an important problem that merits immediate expenditures and action. There is considerable evidence that science is infrequently taught in elementary schools (e.g., Ebmeier and Ziomek, 1983). Furthermore, participants at this conference generally agreed that instruction in mathematics and science is often inadequate, however, because of a lack of research in this area, few participants described specific changes which are needed. Not only do we need more and better qualified teachers, we must also have improved curricula, textbooks, instructional theories, and procedures for making mathematics and science more meaningful. Although it may be appropriate that some additional time should be spent on mathematics and science instruction, the quality of the curriculum and the quality of teaching should be our most important concern.

Before science and mathematics curricula and instruction are altered effectively, however, educators, researchers, mathematicians, citizens, and teachers must comprehensively assess the curriculum and instruction currently offered in American schools in order to make intelligent decisions about changes which are necessary. This is because we not only need citizens who are scientifically literate, but citizens must also have a sense of history, the ability to express themselves, and an appreciation of and skills necessary for participating in the democratic process, etc.

It is clear that the entire American public school curriculum needs serious study. We believe that many courses in the present curriculum are unneeded and that evaluation and reform of general curricula are necessary steps if we are to take appropriate actions in reforming mathematics and science curricula.

Long-term solutions are possible and funds should be invested in national research and development. The problems related to curricula, teacher shortages, technology, and instruction are general ones. Local school districts currently have limited options for addressing such issues (e.g., they can choose among poor curriculum series). However, State and local districts can utilize the results of national research and development to examine more alternatives and criteria for making decisions about improving curriculum and instruction.



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