DOCUMENT RESUME

ED 275 488 SE 046 675

AUTHOR	Champagne, Audrey B., Ed.; Hornig, Leslie E., Ed.
TITLE	Science Teaching. This Year in School Science 1985. The Report of the 1985 National Forum for School Science.
INSTITUTION	American Association for the Advancement of Science, Washington, D.C.
REPORT NO	ISBN-0-87168-286-9
PUB DATE	Jun 86
NOTE	238p.
AVAILABLE FROM	American Association for the Advancement of Science, 1333 H Street, N.W., Washington, DC 20005 (Member, $9.95; nonmember, $12.95).
PUB TYPE	Collected Works - Conference Proceedings (021) -- Reports - Descriptive (141)
EDRS PRICE	MF01/PC10 Plus Postage.
DESCRIPTORS	Educational Trends; Elementary School Science; Elementary Secondary Education; *Inservice Teacher Education; Mathematics Education; *Preservice Teacher Education; Science Education; *Science Instruction; *Science Teachers; Scientific Literacy; Secondary School Science; *Teacher Improvement; Teacher Recruitment; *Teacher Supply and Demand; Technology

ABSTRACT

Issues related to the improvement of science teaching are examined in this collection of proposals and papers from the 1985 National Forum for School Science. Generalized comments are offered on strategies for strengthening science teaching and on selected proposals concerned with the recruitment and retention of science teachers. Topic areas addressed in the forum's presentations and background papers include: (1) science teaching in a global society; (2) a chemist's view of science teaching; (3) producing curriculum-proof teachers; (4) science teaching in a technological world; (5) a sociological perspective on teaching; (6) production and utilization of talented science teachers; (7) the need for generalized science literacy; (8) economic and policy trends and proposals; (9) empowering science teachers; (10) a teacher's view of the situation; (11) science teaching 1985; (12) economic and policy trends affecting teacher effectiveness in mathematics and science; (13) excellence and equality: the contradiction in science teaching; and (14) curriculum-proof teachers in science education. Appendices contain the forum's program, a participant list, and a compilation of statistical information on science teachers. (ML)

This Year In School Science 1985

Science Teaching

NFSS

Audrey B. Champagne
Leslie E. Hornig

2

American Association for the Advancement of Science

This Year in School Science 1985

Science Teaching

The Report of the
1985 National Forum for School Science

Edited by
Audrey B. Champagne
and
Leslie E. Hornig

American Association for the Advancement of Science
Washington, D.C.

The AAAS Board of Directors, in accordance with Association policy, has approved publication of this work as a contribution to the understanding of an important area. Any interpretations and conclusions are those of the authors and do not necessarily represent the views of the Board or the Council of the Association.

Printed in the United States of America

AAAS Publication 86-6

1333 H Street, N.W., Washington, DC 20005

ISBN 0-87168-286-9

ISSN 0888-4358

4

Contents

List of Tables and Figures vii

About the Forum xi

I. Reflections on *Forum '85: Science Teaching* 1

II. Presentations at Forum '85

Newt Gingrich
—on science teaching in a global society 13

George Pimentel
—a chemist's view of science teaching 22

Patricia Albjerg Graham
—on producing "curriculum-proof" teachers 29

Pamela Surko
—on science teaching in a technological world 32

Edward B. Harvey
—a sociological perspective on teaching and the conflicting ideals of American culture 41

Erich Bloch
—on the production and utilization of talented science teachers 47

M. Carl Holman
—on the need for generalized science literacy 53

Paul E. Peterson
—on economic and policy trends and proposals 58

Gordon Ambach
—on empowering science teachers 62

Amado J. Sandoval and Doris Sandoval
—a teacher's-eye view of the situation 67

III. Background Papers

Audrey B. Champagne and Leslie E. Hornig
Science Teaching 1985 77

Paul E. Peterson
Economic and Policy Trends Affecting Teacher Effectiveness in Mathematics and Science 102

Edward B. Harvey and Lorna R. Marsden
Excellence and Equality: The Contradiction in Science Teaching in America 126

Patricia Albjerg Graham and Michael Fultz
"Curriculum-Proof" Teachers in Science Education 148

Appendices

A. Forum '85 Program 175

B. Participants 183

C. Statistical Information on Science Teachers 199

Tables and Figures

Tables

1. Questions germane to science teacher quality. 80

2. Change in average performance of United States students on mathematics and science examinations. 105

3. Average annual salaries for elementary and secondary school teachers as compared with those for full-time employees in all industries. 109

4. School age population, 1960–1990 (thousands). 110

5. Average annual salaries of elementary and secondary public school teachers. 110

6. Percentage of the gross national product spent on public elementary and secondary education, 1949–1985 (billions, unadjusted dollars). 111

7. Percentage distribution of federal NDEA funds among subject areas. 119

A–1. General education: science taken. 201

A–2. Number and percent of graduates by levels of mathematics taken. 202

A–3. General education credits taken by elementary and early childhood teachers (N = 1,251). 203

A–4. Percent of graduates completing at least nine hours in science disciplines. 203

A–5. Percent of graduates not completing a single course in science disciplines. 204

A–6. Hours of science taken and percent of credit in major. 204

A–7. Intended undergraduate fields of college-bound seniors by SAT scores, 1980–81. 206

A–8. Trends in Graduate Record Examination mean verbal and quantitative test scores by field, 1970/71–1977/78. 207

A–9. Elementary teachers' perceptions of their qualifications to teach each subject. 208

A–10. Percent of secondary teachers of each subject who feel inadequately qualified to teach one or more of their courses. 208

A–11. Certification in field currently teaching of newly graduated full-time elementary/secondary school teachers, May 1981. 209

A–12. Certification of newly graduated teachers, 1979–1980. 210

A–13. Percent of newly employed, but unqualified, science and math teachers. 212

A–14. Percent of emergency science and math teachers hired in 1981–82. 212

A–15. Teacher certification requirements. 213

A–16. Secondary school teachers assigned to mathematics and science classes in public schools in 1979–1980. 220

A–17. Alternative estimates of annual demand, supply, and shortage of high school mathematics and science teachers. 221

A–18. Science enrollment, grades 7–9, 1981–1982. 222

A–19. Science enrollment, grades 10–12, 1981–1982. 223

A–20. Changes in science enrollment, grades 7–9, 1977–1982. 223

A–21. Changes in science enrollment, grades 10–2, 1977–1982. 224

A–22. Regional science enrollment, grades 7–9, 1981–1982. 225

A–23. Regional science enrollment, grades 10–12, 1981–1982. 225

A–24. Minimum high school graduation requirements in mathematics and science, as of August 1984. 225

A–25. Percent minority enrollment and teachers in Montgomery County, Maryland. 227

A–26. Estimated supply of secondary science and mathematics teachers, 1980 and 1981. 229

A–27. Estimated supply of secondary biology, chemistry, physics, general science, earth science, and mathematics teachers by state, 1980–81. 229

A–28. Supply of individuals with mathematics education and science education degrees granted, 1971–72 to 1979–80. 231

A–29. Bachelor's degrees conferred in selected areas of education, by level and specialty, 1971–81. 231

A–30. Earned degrees in mathematics and science education, by level of degree and sex, 1979–80. 234

A–31. Percent of male and female teachers of science, mathematics, and social studies, by grade range. 234

Figures

1. Planning cycle for fulfilling science teaching needs. 79

2. Factors that influence demand for science teachers. 86

3. Factors that influence the supply of science teachers. 91

4. Academic ability of prospective teachers is declining. 107

5. Bachelor's degrees and supply of new teacher graduates, 1969–70 to 1990–91. 109

A–1. Vocabulary, reading, and mathematics test scores of high school seniors intending education majors compared with other intended majors. 205

A–2. Qualifications of new teachers for the field they are currently teaching, 1981. 211

A–3. Teacher certification requirements: New York. 215

A–4. Teacher certification requirements: California. 216

A–5. Instructional certification requirements: New Jersey. 218

A–6. Letter to applicants concerning New Jersey's alternate route to teacher certification. 219

A–7. Percentage enrollment in eight science courses, grades 9–12. 221

A–8. Minority enrollment as percent of public elementary/secondary school enrollment, by state. 228

A–9. Student teacher supply index (science), based on 1971 supply. 232

A–10. College freshmen indicating teaching as probable career. 233

A–11. Employed teachers and teacher layoffs and shortages by field as percent of total employed teachers and teacher layoffs and shortages. 235

A–12. Status of the mathematics and science teaching force. 236

A–13. Math and science teachers: entrants and attrition. 236

A–14. The best qualified teachers are the most dissatisfied. 237

A–15. Opinions of public school teachers toward their profession: 1961, 1966, 1971, 1976, and 1981. 238

About the Forum

The National Forum for School Science is part of the Office of Science and Technology Education (OSTE) of the American Association for the Advancement of Science. Each year, the Forum collects and analyzes information about a particular issue in science education, and sponsors discussions on that topic. Volumes in the *This Year in School Science* series extend the information and discussion to those who are unable to attend the Forum meetings, and preserve the deliberations for further examinination. The Forum operates on a three-year cycle (focusing in turn on the topics of Science Teaching, the Science Curriculum, and Science Achievement), so that progress in policy and practice can be monitored over time.

The Forum project is funded primarily by the Carnegie Corporation of New York, with additional support from AAAS. Major intellectual and logistical contributions have been made by the staffs of OSTE, the Office of Opportunities in Science, and the Office of Meetings and Publications.

Project staff:

Audrey B. Champagne, *Project Director*
Leslie E. Hornig, *Program Associate*
Patricia Druger, *Staff Assistant*

Advisory Board

Richard Berendzen
President, The American University
Donald N. Langenberg
Chancellor, University of Illinois at Chicago
Sally K. Ride
Astronaut, NASA
Maxine Singer
Chief, Laboratory of Biochemistry, National Cancer Institute
Richard C. Wallace, Jr.
Superintendent of Schools, Pittsburgh, Pennsylvania

REFLECTIONS ON FORUM '85: SCIENCE TEACHING

On October 10 and 11, 1985, some 300 people met in Washington, D.C., to discuss the quality of school science teaching. They were drawn by the promise of fresh analyses and a chance to reconsider familiar problems in an imaginative cross-disciplinary way.

Forum '85: Science Teaching was organized to examine the forces—social, economic, political, and educational—that influence the quality and supply of science teachers in the United States. For the Forum, project staff analyzed quantitative and qualitative data. Background papers were commissioned to examine the issues and propose new directions. At the national meeting, the diverse group of participants responded to these analyses and proposals, and exchanged some of their own. Their goal was to develop a better understanding of the education system and how it could be restructured to improve science teaching.

Forum discussion focused on four topics:

1) Values held by society, the scientific community, and the education community, and the consequences for science teaching of incongruities in these value systems.
2) Costs and benefits of alternative models for the professional education of science teachers.
3) Economic and social circumstances of science teachers, and their implications for the supply and quality of science teachers.
4) The social climate and organization of schools, and their influence on the effective use of science teachers.

Results of the Forum presentations and discussions are summarized in the section of this chapter titled "Proposals for Action." Many of the proposals will be familiar to readers who have struggled with these issues. "Setting Priorities" extends the Forum discussions to examine other considerations that contribute to the development of plans of action. A systems approach to planning is illustrated in this section. Central to the approach is careful analysis of the premises and consequences of proposed actions; such analysis helps prevent proliferation of costly errors in our decentralized education system.

A Strategy for Analysis and Planning

Establishing and maintaining an adequate supply of qualified science teachers is a difficult task because it must be accomplished within a complicated political and social system in which no single institution is responsible for maintaining the quality of science teachers. Proposals for strengthening science teaching often lack coherence because they ignore significant interactions among parts of the system. Institutions within the system that influence the supply, demand, and quality of the science teaching force are: 1) schools, where teachers practice their profession; 2) universities, which educate teachers; and 3) state and local governments, which set educational standards, certify teachers, and determine conditions of employment. These institutions operate in communities whose boundaries may be local, state, or national.

Although each institutional subsystem has a limited functional responsibility, they influence each other. Specifying the nature of the interactions is necessary to the planning process because an action taken by one subsystem will have effects on the other subsystems; one unit's solution may well create another unit's problem. For example, many states have enacted legislation to increase graduation requirements in science. Local school districts charged with finding qualified teachers for extra courses at a time when qualified science teachers are in short supply will find the impact significant. Effects can be beneficial as well; demand for new science teachers may influence colleges of education to develop state-of-the-art science teacher education programs.

Systems analysis highlights two important points: 1) while our educational problems are national in scope, their solution will depend ultimately on local action; and 2) poorly informed political action can exacerbate educational problems rather than contributing to their solution.

Expanding on the first point, national commissions may recommend a particular action, but states and local school boards must implement that recommendation. Local boards may decide that nationally-based evidence is unconvincing, or that it is irrelevant in their communities. They may lack financial resources. Or they may simply decide that other issues take precedence. If local boards do take action, chances are that the action will not be coordinated with neighboring districts or states.

There are many illustrations of the second point—the negative effect of impetuous political action—in the recent history of education reform. The national study commissions trumpeted recommendations on a grand scale, but many of their recommendations are, on careful analysis, either unattainable or unlikely to have the intended outcome. The rush by the states to beef up graduation requirements is another example. The general conclusion to be drawn is that uninformed political solutions to educational problems are unsatisfactory. National reports and legislative action typically do not take educational and economic constraints into consideration. Because they are politically motivated, they sacrifice long-term solutions in favor of immediate, incomplete, and occasionally perverse results.

Setting Priorities

In spite of the opportunity for disagreement that such a complicated education system engenders, deliberations at the Forum were remarkably free from discord. Premises and assumptions went unchallenged, and with few exceptions participants received all recommendations for action equally. There was unanimity in the ranks of the Forum—a unanimity that seems to have existed also in the conclusions of other education commissions and committees. Given the apparent strength of the accord within the scientific and science education communities about what needs to be done, why are the problems of science education so intractable?

First, agreement is easy when the stakes are low. What participants proposed at the Forum were general recommendations, not specific action plans. It is always easier to agree on generalities than specifics. Also, the Forum deliberations were removed from the political and economic constraints that exist in real life. When reforms are discussed in the abstract, resources and reputations don't hang in the balance. Agreement is affordable.

Second, accord isn't always beneficial to the process. Any proposal merits serious review: Is it likely to have the intended effect? Will it be cost-efficient? Might it produce harmful effects elsewhere in the system? Critical examination of proposed recommendations helps prevent inappropriate and costly action.

Third, resources available to improve a situation are not unlimited. Consequently, responsible parties need to choose among the proposed actions and set priorities for implementation. The evidence and arguments contained in the Forum speeches and background papers can inform this process.

The kind of discussion that took place at the Forum is a highly useful first step because it can develop a universe of possible policies and actions. Those who are responsible for implementing reform programs, however, will want to review the proposals carefully to find a combination of actions that will optimize improvement of science teaching in their jurisdictions.

Some recommendations are immediately attractive because they are conceptually simple. Others are forthrightly noxious. But there ought to be overriding considerations: whether a proposal is likely to have the desired effect; whether it will have negative side effects; and whether it can be implemented—that is, whether it is economically feasible and politically palatable. The first step in the assessment is close scrutiny of the assumptions that underlie the proposal.

For example, consider the proposal advanced at the Forum to improve science teacher quality by paying science teachers more. The rationale is that schools have to compete with industry for the brightest scientifically trained people, and to do that they have to offer salaries that approach those offered by the private sector. At least eight premises precede this proposal:

1) People exist who would make better science teachers than some of the ones we currently have, or are likely to have, given current salaries.
2) These people are able to find work in the private sector.
3) They choose to work there primarily because of the financial compensation.
4) If they were offered more money to teach than is currently the case, they would choose to teach.
5) School districts can identify, from a pool of applicants, who will make the best science teachers.
6) Only the most able applicants will be hired.
7) Those who are attracted by the money will stay.
8) The quality of science teaching depends more on the ability of the individual teacher than it does on the environment in which it occurs.

Even without collecting evidence, it is apparent that if an underlying premise is false, the action probably will fail. Is it true that better science teachers can be found? If not, recruitment is a futile strategy and money would be better spent retraining current teachers. Can they be distinguished from all other applicants? If you can't identify who will make the best science teachers, all the money in the world won't buy improvement. Given the current hiring system and union contracts, will they be hired preferentially? Unless there is freedom to hire the most qualified person for the position, regardless of seniority or of other constraints, you may end up paying increased wages to the same ineffective teachers.

Unfortunately, evidence that either supports or rejects these assumptions is sparse, as it is for most of the issues connected with science teacher quality and supply. Many of the studies that do exist are flawed or incomplete. But they are cited—sometimes erroneously—as evidence for this or that, because they are the only ones available. One of the first conclusions this analysis reaches is that the quantity and quality of research on science teachers, and teachers in general, needs vast improvement.

A second conclusion is that for some premises validity comes by degrees. For example, the validity of the premise, "If they were offered more money to teach than is currently the case, they would choose to teach," undoubtedly depends on how much more money is offered. Some people come cheap, others demand a higher price. Would the quality of people that a district attracts increase as the salary increases? How much more would a district have to pay to improve science teaching by *x* percent?

Finally, even if all the premises are found to be valid, it cannot be assumed that a particular strategy will achieve the desired end. In the current example, offering higher salaries may well enable a district to attract higher caliber science teachers. But will this have any appreciable effect on science teaching quality overall? In the short run, it may not, because the district probably will be limited to filling vacancies as they occur through attrition. (At the Forum, New York State commissioner of education Gordon Ambach placed the annual turnover between 2% and 8%.) Over 10 or 15 years, however, if the policy were implemented, average teaching quality would increase. The policy would be appropriate for districts looking for a long-term solution, but not for those seeking immediate results.

Once the proposal that raising science teachers' salaries will improve science teaching quality has been confirmed, the focus shifts to the cost and possible unanticipated consequences of implementing the action. A possible consequence of paying science teachers more than other teachers is bitterness and conflict among teachers and, more formally, conflict with the teachers' union. Also, allocating more money for salaries over a long period of time will mean that there is less money in the budget to improve science laboratories or to purchase chemicals and supplies. This may mean that the very teachers who are attracted by the higher salaries will decide against taking jobs in the district because laboratory facilities are inadequate. Might it not be wiser to allocate some portion of available resources to salary, and some to laboratory equipment and supplies? If so, how much to each?

Proposals for Action

A systems approach to analysis and planning is a useful tool, but its contribution to effective planning is only as good as the proposals it is used to consider. Discussions at the Forum included many of the same proposals that have been advanced over the last few years. They are a good starting point for looking at ways to keep science teaching current with our needs.

Values

The values that society holds about science and education can contribute to or impede the development of effective science teaching. The papers prepared for the Forum by Peterson, Harvey and Marsden, and Graham and Fultz identify incongruences among the values commonly held in the professional communities and in society at large. Each paper makes the case that incongruent values contribute greatly to the general problems of science education, and specifically to the recruitment and retention of good people in science teaching.

Peterson, for example, attributes the nation's recurring problems with science and mathematics education to the incompatibility of the intellectual skills that science and math instill with the habits of mind valued by the American culture. America, he says:

> is an egalitarian society where everyone stands on an equal footing and where verbal acuity and personal expressiveness count for much in making one's way in the world. And the American economy runs by the principles of the marketplace, an arena which demands high level bargaining and negotiating skills. In such a society, the scientific method and the order that mathematics imposes takes second place. Unlike the ceaseless spontaneity of the United States, such precision better suits the Japanese or European countries.

Peterson's conclusion is that the problems of math and science education are so deeply rooted in the culture that they cannot be changed by activities of the educational system.

Harvey and Marsden point to equality of opportunity and excellence of achievement as American ideals in conflict, a conflict that creates tensions in the teaching force. These tensions originate in the national reports' recommendation that an elite corps of science teachers be created, because the recommendation ignored the tradition of equity that lies at the heart of the occupation. The conflict extends to the curriculum. Should the schools teach pure science? Or science combined with its applications and social consequences? The dilemma this produces is that the brightest people may not be the most appropriate choices for teaching a diversified science curriculum to the general student body. Because we want to pursue both equity and excellence, Harvey and Marsden conclude, it is more difficult for us to achieve either.

This tone of pessimism, expressed in all three of the commissioned papers, is grounded in the basic incongruities the authors perceive in our society's values. Is it true, as these authors argue, that educational reform is unlikely to occur without significant change in society's values? Congressman Gingrich offered some hope, expressing the belief that it is difficult but not impossible to change values and align them with the nation's current needs. Toward this end he offered two suggestions: 1) provide continuing education for adults in the scientific method and in its relevant patterns of thought and discipline; and 2) investigate the traditional values and family habits that lead Asian Americans to learn math and science better than any other subgroup in our culture.

Alternative Teacher Education

Forum participants, especially the practicing teachers and scientists, favored a shift in teacher education and certification that would emphasize discipline knowledge and practical teaching skills, and de-emphasize pedagogical theory. Practicums and internships, supervised by mentors and master teachers, were recommended for practice in the art of teaching.

There was also support for alternative certification requirements and procedures. Current credentialing methods were said to place too much faith in input measures, such as credit hours, and to depend too little on direct measures of knowledge and teaching ability. People worried that the current requirements are too stringent, and for the wrong reasons; the emphasis on education course work was feared to influence some potentially good teachers to reject teaching careers. It was suggested that ongoing professional evaluation can help reduce the risk associated with innovative credentialing systems.

Professional development was also recommended to ensure continuing science teacher excellence. Solid, graduate level courses in a teacher's discipline were applauded. Participants called on universities to schedule graduate courses at times when teachers can enroll (most now take place during teachers' working hours), and on school districts to grant and finance leave time. Paid sabbaticals were also recommended for teachers who need time to learn about advances in their fields or develop new curricula.

Economic and Social Circumstances

Forum participants agreed that the total compensation package offered to science teachers is inadequate to attract and retain top talent in the science teaching force. They proposed that the most useful action to attract talented teachers would be to raise salaries for science and math teachers, so that schools can compete fairly with industry for the brightest college graduates.

The discussions made clear, however, that improving the social status and prestige of teaching is just as necessary to attract talented teachers. The intrinsic satisfaction of helping students develop is often cited by teachers as their primary motivation; if society does not reward this important function, that satisfaction may diminish. The paper by Harvey and Marsden notes that, sociologically, teachers occupy a sub-professional niche that earns them less respect than true professionals, although it argues that teaching traditionally has been a route of upward mobility.

The most concrete suggestion for both raising respect and providing science teachers with real resources was to improve the integration of science teachers into the scientific community. Professional and scientific organizations were urged to grant teachers "first class citizenship," to involve them in association activities, and to target activities to their needs. In his presentation, Gordon Ambach hailed the empowerment that teachers derive from meaningful contact with their scientific colleagues. Several discussion groups advocated increased interaction among science faculties at all levels, from elementary school through college, by one-on-one contacts and regular meetings modeled on county medical and bar societies. Three benefits were observed: solving science teaching problems at all levels; increasing the respect accorded to science teachers; and integrating the science curriculum across educational levels.

Social Climate and Organization of Schools

Participants at the Forum believe that the environment in which science teachers teach is almost as important as the people who do the teaching. They recommended that schools reinstate an educational focus, so teachers don't have to compete for the students' attention. More resources, such as better lab facilities, were recommended; so was administrative support for productive teaching and learning environments, even when they encourage lively activity on the part of students. Teachers who engage students' active participation in science should be recognized, not criticized, for their teaching practices.

One recommendation was that unqualified teachers should not be assigned to teach science classes, especially at the elementary and middle school levels. The majority of discussants said that cancelling a course or unit was preferable to allowing incompetent teaching to jeopardize students' understanding, or worse, their appreciation, of science. Some state administrators, however, said that science courses should not be withheld from students who need the class to get into college, regardless of teacher competence.

Complex Decisions for Complex Systems

Making decisions about the allocation of funds, time, and expertise is, as the mathematicians would say, a nontrivial optimization problem. The process requires determining each possibility's intrinsic worth, trading off the costs and benefits of multiple options, and making decisions about which ones to pursue and what portion of available resources to allocate to them. Deciding whether a proposed action or set of actions can be successfully pursued requires a separate, but no less complex, analysis of the factors aiding or complicating implementation.

What makes the problem even less trivial is that such decisions are made throughout the system by operating units that function with little consideration for their effects on others. An affluent district can attract highly qualified science teachers to teach in well-equipped laboratories at the expense of a less well-heeled district a few miles away, yet students in both schools are expected to attain the same state-mandated level of science competency. This is one kind of intrastate interaction. Interstate interactions also occur. Salary incentives can boost supply in one state by attracting teachers educated in a neighboring state. Many examples exist of interactions between the states and national organizations. For example, standards for science teacher preparation set by national associations are rendered ineffectual when state credentialing boards and teacher educators choose to ignore them.

In Conclusion

Forum conversations produced a long list of recommendations not unlike those generated by the many committees and colloquia that have considered the problems of science education and education generally. An unexamined list of recommendations, even if highly creative, cannot make much of a contribution to the improvement of science teaching. How does such a list get turned into a plan for action?

One important step in the planning process is careful analysis and assessment of recommendations. Which proposals are well-founded? What is the likelihood that the best-conceived recommendations can be implemented? Another step is to optimize the allocation of resources to those policies deemed most likely to be effective.

Where does responsibility for planning and implementation reside? How do representatives from the many responsible institutions cooperate so that their efforts do not undermine one another? How will the necessary resources be obtained?

These questions have yet to be addressed in a coordinated fashion. Efforts to improve science teaching can proceed along both substantive and political lines. Thus far, most of the action has been political, with far too little input from the education and scientific communities. It is the responsibility of both these communities to make their message well-reasoned and coherent.

The Forum project will continue to monitor the condition of science teaching; Forum '88 will return to the topic. Your experiences with planning and implementing programs to optimize science teaching will be useful to that discussion. Please keep the Forum informed of your work.

—Audrey B. Champagne and Leslie E. Hornig

II. Presentations at Forum '85

Newt Gingrich, *Member, U.S. House of Representatives (R–GA)*

— on science teaching in a global society

I appreciate very much the chance to be here. I just told Dean Graham that I thought the height of optimism was to have a Director, a Dean, and a Congressman as your opening round and think that you are going to be done on time. I should say to all of you, by the way, to help better focus where I come from that I am the Congressman who represents the Atlanta airport, and one of the questions I always ask in groups like this is how many of you have been through my district? Raise your hand if you have been through the Atlanta airport. I once had a guy at West Point yell from the back of the room, "Ask how many people enjoyed it." But, we have 35,000 jobs there. And it's a very positive thing for us when you can get scheduled through there— so feel free to come by and change planes as often as you can.

I was very, very honored to have a chance to come here. I am a member of AAAS. I read *Science* magazine. I suspect I read about half the issues a year. That and *The Economist* are the two magazines I read most frequently. I think that *Science* is a very important contribution to public education. I appreciate it very, very much. And, therefore, I was very flattered with the idea that as a once-upon-a-time history teacher I could drop in and say my piece. I'm also fascinated and impassioned in my commitment to education. I have some fairly radical thoughts, and I wanted to have this chance to talk to people who are professionals in the field. So, I am going to run through what should be a book. I have tried to compress it to an article. And today, for time reasons, it is going to become an abstract. I am going to give you a very skeletal overview. All of you have a booklist that we put out. It's the Conservative Opportunity Society Booklist. I particularly recommend the first book on the list which my wife and I wrote. That is the one book we urge you to buy. Although we think you should check the others out of the library at a minimum. A couple of the ideas I am going to talk about are in the book. So, for more detail you might want to go to it. I am going to go through an outline and jump from point to point. It's a sequence of thoughts so I hope that I won't be too incoherent.

First of all, science education from a public policy standpoint is important. It's important economically. We need more scientists and engineers. In the age of DNA and the computer, basic science knowledge is as important as basic internal combustion and mechanical engineering was in the age of steam. We have not really integrated that into our thinking about what it means to be economically useful in the

21st century. To understand public policy issues, science and the scientific approach are increasingly important. Whether you are trying to understand Three Mile Island, trying to understand whether we should go toward nuclear power, trying to understand the risk factors in, for example, the spread of AIDS—in every one of those cases understanding the scientific method and the framework of asking intelligent questions are important for every adult citizen.

Scientific illiteracy is a threat to the very survival of our free society. I will say to you in passing, for example, that John Platt's superb article, "Strong Inference," which is in a 1965 issue of *Science* is the most powerful single article I have ever read as a public policymaker. And I use the principles of strong inference on a daily basis. I think that until we learn how to translate the process of right behavior—that is right scientific behavior in the sense of how to ask questions that give you choices which you can then test—until that becomes a normal habit of an early 21st century global community, we are going to have very grave problems with where we are going.

In that sense, although many of you, I think, think of yourselves as educating people who are pre-adult, we have to confront the reality that adults need science education and an understanding of the scientific method as much as kids—and that because we don't do it well, now—we either have to resign ourselves, because of the length of time generations take, to not getting around to it until the middle or late 21st century or we have to figure out how we are going to catch up with all of the people we missed in the last 50 years.

I would argue that a part of continuing education for adults is the scientific method and the patterns of thought and discipline that are part of the scientific method. Alvin Toffler, in particular, has made the point eloquently that cultural education is vocational education if you are making the transition from an assembly line industry to a knowledge industry. One of the reasons that it is so difficult right now for adults in their forties to make a shift from autos and steel to working in a knowledge industry is that is a cultural value habit shift, not a vocational shift. And there are underlying patterns of thought and self-discipline that are key to that.

I would suggest to you that yesterday's William Raspberry column on the cultural values of learning—that is, the culture of work, the culture of discipline, the culture of doing homework—is extraordinarily important and is something that conservatives have been inarticulate and incoherent in trying to say for 40 years. Similarly, today's article on page 1 of the *Washington Post* about Asian Americans as model learners is important. Our goal in life should not be to figure out how to get the Asian Americans to be more like the liberal welfare state. Our goal should be to figure out what the underlying traditional value and family habits are that lead Asian Americans to learn math and science better than any other subgroup in this culture.

The key to real change in scientific literacy for Americans involves five paradigm shifts. Now, obviously I am deeply indebted to Kuhn's structure of scientific revolutions, which may or may not be accurate history but is remarkably useful thought. I mean very often we can be grateful that somebody figured something out even if they were wrong in the reason why they figured it out. And, I am not going to argue with people who know more than I do, whether or not, in fact, the Newtonian revolution occurred the way Kuhn said it did or the way a recent volume that just came out—which I borrowed from the Library of Congress because it was reviewed in *Science*—describes the way revolutions in science occur.

Let me suggest to you a concept which is the one thing I would hope you will write down today and then if you get real excited you can write down the five shifts later. It's a concept that I want to walk through and I want to tell you in advance that it is based in part on Kuhn and in part on military and business thinking about how you plan in the long run. The concept is very simple. It is that all human activity occurs at four levels. You have to have four lines to write this—it's a hierarchy. The bottom line is *tactics*. What do you do every day. (I walk in a classroom and I write on a blackboard.) The level above that is *operations*. How do you package your tactics into a program. (I teach Physics I.) The level above that is *strategy*. What do you hope to accomplish with a series of operations? (We hope to produce physics majors.) The level above that is *vision*. What do you think you are trying to accomplish?

In education, probably, Eliot's vision of Harvard is as good an example of vision-level leadership that took 40 years to implement as any single vision in modern time. The rise of graduate education, the transference to America of the German vision of graduate education of the 1880s and 1890s would be another example, Johns Hopkins in that case. The best place to study this in the business world is Alfred Sloan's memoir of his years at General Motors and his two chapters on how they rethought GM when it was going bankrupt in 1921. They started by rethinking America and they concluded that America was getting richer and that when it got richer, by definition the automobile would cease to be transportation and would become status. That's a vision-level concept.

Henry Ford defined the automobile as transportation which is why he built the Model T in any color as long as it was black. General Motors decided that as we got richer, we'd start to buy status and that we would have a very high value in proving to our relatives that we were rising and we would do so in the GM plan by buying a General Motors car. That required them to do three things. They invented the annual model change, which was an enormous engineering achievement. Second, they consciously positioned the market so you always bought "up" from a Ford product to a GM product. You went from Ford to Chevrolet. You went from Mercury to Oldsmobile. You went from

Lincoln to Cadillac. Third, they literally invented the authorized used car dealership because it turned out that once you owned a car, even if you got a promotion, if you couldn't get rid of the car, you couldn't buy a better one. Now these are strategies of change that made General Motors the dominant industrial corporation in the 20th century. You see a little bit of the same pattern in Ray Kroc's book, *Grinding It Out*.

To get a good vision-level sense of where we ought to go, I would suggest you read two books by Peter Drucker, one of which is on our booklist, *The Age of Discontinuities*, now 15 years old and still relevant which is a sign of how little we've changed and how important vision level books are. The second is his newest book, *Innovation and Entrepreneurship*, which is the best single book to read if you want to understand how to change where you are at. It is a superb work on how to reorganize and rethink and run experiments, and emphasizes what terribly hard work it is. In addition, I would recommend, if you're serious about this level of thought, that you read Bolding's *The Meaning of the 20th Century*, Daniel Bell's *The Post-Industrial Society*, Toffler's *The Third Wave*, and Naisbitt's *Megatrends*.

When you read those you will get the sense that we are as a culture going through a vision-level change which all of you sort of know in that we are moving from what I would call an assembly-line industrial society to an information industrial society. I emphasize we are not deindustrializing the human race. This is nonsense. It's like saying we have deagriculturalized the human race because most of us don't work on farms. We, in fact, don't work on farms because they are now so productive that most of us don't need to work on farms and can go do something else. In fact, have to go do something else.

In the same context, I'm suggesting to you, for our own thought processes, it helps to think about shifting from an assembly line industrial society to an information industrial society, and drop all this nonsense about service industries. Service industries are buying McDonald's hamburgers or getting your hair cut. What you do is not a service industry. It is an increase of human productivity by the application of knowledge. A very big difference. If you read Adam Smith's, *The Wealth of Nations*, you will see that he describes rises in productivity by knowledge as the most valuable and most expensive of all investments. But Adam Smith, in fact, is not a laissez-faireian. He believed very deeply in public education.

In that framework, let me suggest to you then that the problem we face in education at every level, and it applies to science education as a subset, is that we have inherited an enormous cultural, professional, and bureaucratic model that we call public education in the broadest sense, but this applies to the private schools, virtually all of which are simply built on the same paradigm, which is an 1840s invention. It is a textbook-, blackboard-, teacher-dominated environment that treats grades by age and credentialing as though they had meaning. Now, all of those are obsolete. The underlying question is how good is the professional cast going to be at maintaining an obsolete system by sheer power and how good are the political unions going to be at grabbing resources by sheer power? None of that has anything to do with the real world, except, of course, in the short run, at a tactical and operational level the real world is what you can gauge.

In the long run, I would suggest to you that if you are really honest and you really look at Platt's concepts, and you read Kuhn and you read those other books, you will come to the conclusion that the two great questions are: (1) what is the model of learning in the 21st century, and (2) how do we manage the transition to it. And that 99.9% of what we are currently doing is, in fact, simply tactical and operational bandaids on a vision that is now essentially out of date.

In that framework, let me suggest five specific paradigm shifts. This is the only other thing you may want to write down. I don't have time to explain them in much detail. The first is from teaching to learning. Public education in the 1840s model was a teacher-dominated environment. Almost all knowledge workers are by definition internally driven and want the data they want at a faster rate than teachers can codify it.

So, it becomes a market-oriented function of you looking for where you find the knowledge, not you waiting for the teacher to ramble through the point that you want. That's why, for example, almost no adults voluntarily go to school if they can avoid it. You have to require certification to get people to go back to school because going to school is a remarkably inefficient way of learning. You learn what you intend from people who are mentors, by apprenticing yourself, by going to the library, by using videotapes, by using computer systems, but by having the learner direct the process, not the teacher. That first—if you just think that one through—that's radical enough, it probably wipes out most of modern education.

The second one which puts the cap on it is we have got to shift, if we're going to survive in a competitive world, we have got to shift from credentialing to achievement. The best student I ever had is now working in the White House, was my Administrative Assistant, wrote a paper on foreign policy that marginally changed American politics, and is five hours short from graduating from West Georgia College. He would clearly not be allowed to teach in any public school system in America today. Yet he is a national class writer. That's nonsense. That's just stupid. The society that voluntarily punishes itself like that is just incredibly dumb.

We prop up the dumbness in the name of professionalism and in the name of trade unions but, in fact, it's just dumb. And we can't afford it. It's also incredibly dangerous because people come to believe in the credentials. If we decide to have malpractice for education and make it personally liable, which after all is the other half of being a professional, then I think you will instantly expose the sham we are living under because education in its current form is not a profession. It is a bureaucracy. And there are very few teachers who would be willing to say, "Yes, I am a professional. Pay me what I'm worth, and if I fail, you can sue me for malpractice." Now, I'll let you go out and test that one in the marketplace, but I think you'll find there are very few people who will accept that tradeoff, which is the central test of professions.

Third, we have got to move from age-graded to lifetime learning. If I see an illiterate at 40, that person should be in first grade, and, in fact, back when people arrived as immigrants, that was the norm. I just recently read a fascinating novel called *The Auerbach Inheritance* which is about being Jewish in New York City at the turn of the century. When you read from the perspective of the immigrant what it meant to become American, it meant you did what made sense. And if you didn't know how to read English, you went to the first grade, and if that meant you were 27 years old in the first grade, that was all right. That's where you were in life. And if you learned fast enough, you didn't have to stay in the first grade all year. If you didn't learn fast enough, you got to stay in the first grade a long time.

We have just made nonsense out of this concept of grades. Both of my daughters spent their entire senior year in high school purely for social reasons. Learned nothing. Cheerfully learned nothing. Let me tell you, that is degrading the concept of education. It is a waste of a year of their productive life and it's stupid.

Trapping young black males into a school at 14 is dumb if they want to go out and earn a living—if you could then set up a society where at 25, when they are tired of doing really dirty work, they go back to school to learn because they are now mature enough. But we have got this whole thing messed up so that they fit our habits. And then we fail, and then we wonder why we fail and then we try to coerce them more. And then when we totally fail, we say, "Well now they are adults, so we can't do anything with them."

Claude Pepper is 81 and recently became an anti-communist. A fundamental change in his whole behavior style. Claude is now actively more anti-communist than George Shultz. It's bizarre. He just introduced a bill to send aid to Savimbi in Angola. He authored the amendment to repeal the Clark Amendment, which had stopped aid to Angola. Claude Pepper has changed largely because he has a lot of Cubans who have been educating him in his district and he is a good politician. But he is learning at 81. Ronald Reagan learns some at 74. That is more than a lot of us can say at any age. Alright? So I'm just suggesting to all of you, if Reagan can learn at 74 and Pepper can learn at 81, maybe the model we have adopted of age gradation is essentially wrong. Maybe people ought to learn all of their lives and we ought to design a learning system that would be publicly financed, but not necessarily bureaucratic that would allow people to learn at the point at which they need to learn.

Fourth, we have to invent contextual learning systems. I spent all day yesterday in a conference that the Center for Strategic and International Studies set up to look at the news media and terrorism. And, Fred Friendly, the man who, along with Edward R. Murrow, invented modern television news and carried it, I think, to its peak, was there. He is now 70. Friendly said the greatest problem in the modern news is the lack of context. It occurred to me that he is exactly right. Not only do we want to learn facts, but when an event occurs we want to learn about the event contextually.

I spent an hour and a half this week with the Acting Head of the Centers for Disease Control discussing contextually AIDS as a tropical disease both in its Zaireian and its American context. I had to know a heck of a lot to be able to ask him the right questions and to have the questions have any meaning. What we tend to forget is that data without context is gibberish. We have never thought through very much how to give people bites of context that are total. It's almost like having a vitamin pill that's a total vitamin pill. When I want to know a scientific answer, I want to know the total contextual framework of how to think about it, what it is, and what does it fit into.

Finally, five,—and, again, this is one I know in my gut is right. I know that what I am about to say to you is exactly right. I'm not sure what it means, and I think we mostly mistranslate it. It is terribly important that we learn how to get people to understand doing science. Okay? And this does not mean going in and playing with chemicals for two hours. It is a way of approaching data. It's a way of thinking. It's a way of being. At least this is my impression. I am not a scientist. I'm just a history buff, but my impression is from having taught environmental studies as an interdisciplinary course and having helped developed it, I worked with physicists and biologists and chemists and a lot of other strange people. Strange included sociologists, philosophers, etc.—historians have this general sense that if you don't immerse yourself in archives, you're weird. My feeling was that the people I knew who were good at science *did* science. It wasn't an abstract thought process. It wasn't a memorization process. It was a way of being. I mean they approached everything with a scientific method. I'm not sure what they were like on a date, but that was a way of thinking and doing.

And it breaks down into subsets. One of closest friends is a physicist who thought that his chemistry friends were genuinely strange. Because physicists and chemists have a different rhythm of approaching data. I'm just saying to you that my fifth paradigm shift is we have learn how to do science, not just how to describe it or how to teach it in context.

I apologize for running quite so long, but as I said I wanted to lay the whole abstract out. Thank you.

George Pimentel, *Director, Laboratory of Chemical Biodynamics, University of California, Berkeley*

– a chemist's view of science teaching

I found one thought that Congressman Gingrich placed in our minds particularly interesting and that was to ask whether professionals shouldn't regard malpractice as part of their professional package. I think it would be interesting to ask Congress whether they would be willing to pass a law that identified them as professionals with malpractice as one of the criteria.

When I first was asked by Jim Rutherford whether I would come and participate today, I indicated a little reluctance to come. I suggested that you would expect me to say something intelligent and Jim knows that isn't easy for me. And he said, "Quite the opposite, George. We want you to be yourself. We won't expect anything intelligent. Just display your biases as you normally do and provoke people." Now I think that you already got a start in the provocative direction with Congressman Gingrich and, again, he'll be a hard act to follow, but I'm going to follow Jim's instructions and do what comes naturally. So if it doesn't sound intelligent, you'll know that I wasn't expected to sound intelligent. I was expected to sound biased and provocative.

In any event, I'm going to begin by offending my hosts who invited me by disagreeing with some of the things they have said. Both Bill Carey and Audrey Champagne. Bill Carey said in the call to this meeting that we should anticipate future trends and needs so that 25 years from now we'll have an entirely new set of problems before us and we will be back together again wondering how are we going to solve these problems. I think that what's important to recognize is that we have some special problems today that we've got to solve and they're different from what they were 25 years ago. So we're going to be here 25 years from now, Bill, and, as you say, we'll have to be in a much bigger hall no matter how much we accomplish on today's problems.

Now what did Audrey say that I'm going to disagree with? She said that a crisis is very inefficient. Now I think that is quite wrong. We need crises in this country. Unfortunately, it seems that we can only get attention to some of our problems with crises. I don't advocate that; I just state it as a fact. And we have now reached a point at which people have recognized the difficulties we are facing in education, all the more critical in an industrialized society with many of the problems identified in a global sense by Congressman Gingrich. We have had these problems for some time now, but we have the beneficial situation that it is now recognized as a crisis and we must take advantage of that. We don't necessarily have to do what the people who are panicked about it say, but let's do something. Let's take advantage of the crisis and count our blessings.

Well, let me talk a little more about my disagreement with Bill Carey about how 25 years from now we won't be asking the same questions and singing the same laments. That takes me back 25 years to the 1960s and our attempts to do something at that time about what was recognized then as a crisis in science education. What I want to argue is that the crisis is different today. What we did at that time was address a problem as seen by society that, by golly, the Soviets had something up there in space and we didn't! What we needed to do was address our science educational system so that we could have better chemists, better physicists, better engineers, and then we'd get something up there too. That was very much on people's minds, and what we tried to do—those of us who tried to respond to this challenge—was see if we couldn't improve very much the education of those then taking science courses, and that represented a very select group of students. They were, first, those students whose academic performance placed them in the top half of the student population, and secondly, they were those who opted to take science.

Our problem today is the recognition that all of society needs to be more scientifically literate. Our challenge is not directed at that science-oriented group but rather at the rest of them, the rest of our students who also must live in an industrialized society. They must participate in a democratic society in making our technological decisions in their own behalf and in everyone's behalf. They vote as well as everyone else. They must do so with some judgment. They must evaluate the performance of their representatives with some perspective, and that requires an increase in scientific literacy. And, believe me, this is a group that's very much more difficult to address than the ones who opt to take science, who come in already with some motivation.

So, that's what I think is so different today. It causes me to address first one of the questions that you are going to be discussing this afternoon, the question of what policy options face us. One of the policy options that faces us requires that we pass from the global view now to a microscopic view. What should we do today? I'm at the tactics level in talking about how to address this problem which has been defined as a crisis but which I think has been around for quite a while, a decade or so. This first policy option that I think we face, which is a tactical one, is how should we target efforts, or *should* we target efforts?

My answer—and this is exposing biases—is that yes, we should target our efforts. We should definitely give special attention to those levels of science education at which we can best focus on the difficulty of addressing this new audience. It is in the sense that 25 years ago that wasn't the audience we were trying to address and there is plenty of evidence that we did quite well for the audience we did try to address. This other group has to be approached in a very different way and a way that isn't so easy. In any event, I say yes, we should target our efforts and we should do so at the middle school level. That will pervade everything I say.

Why the middle school? Well, in the first place it's not K–6, it's middle school. It's not high school. That immediately represents some sort of a selection process. I identify the middle school as the highest leverage spot in our educational system to do something about what I have represented as our immediate problem. First, it offers high leverage because we have there a level of education at which the student cannot opt out. We have an opportunity to catch everyone. Secondly, we have in that classroom lots of individuals we would like *not* to receive the imprint of a society that tends to define for certain individuals, by reason of race or sex or whatever, that science is not for them, or math is not for them. Let's get them first and get them implanted with the idea that science is fun and it *is* for them. It's for everyone. That's just the right place to do it.

Now, why not K–6? Now I'm again telling you my biases. In important ways, the teacher population of K–6 differs from that in the middle school. And, of course, that in the middle school differs from that in the high school. And I feel that addressing the problem of science education at the middle school involves a cadre of teachers where we have the most chance to make big advances. At the K–6 level, there are many other aspects to education that are facing that teacher that may make it much more difficult to improve the science component, so, I am willing to postpone that and focus efforts onto the middle school level.

Now a second issue that we face, which I regard as a policy issue, is the balance between addressing the needs of our existing science teachers versus new teachers. Notice that I'm talking about balance, not eliminating activities in any of these arenas, but rather giving certain ones a deliberate preference. And I think that we should very definitely try to address the needs of the existing cadre of teachers. There are very many of them out there teaching middle school science and they have very great needs.

Now, how do I know that? Well, I have participated myself this summer in an NSF-sponsored institute for middle school teachers, and so I bring to this discussion some immediate experience. I don't mean to say that you don't have equally interesting or important experience, but at least I'm talking about some things that we tried to do and some outcomes of that experiment.

In the first place, let me tell you what we tried to do. This was an institute in which the leadership on a day-to-day basis was by a pair of master teachers, Penny Moore, who is a very successful high school teacher with junior high school teaching experience, and Jerry Smetzer, an outstanding junior high school science teacher. Those were the people who were on the day-to-day firing line and the ones who organized the group and decided specifically what would be done. I make that point as a crucial one: The leadership in this institute was in the hands of people with classroom experience at the middle school level. And now I'm going to read some of the things that appeared in our application to NSF to indicate what we wanted to do: "The teachers will participate full-time four weeks in the summer. During these four weeks, mornings will include lectures and question-answer periods with university professors specially chosen for teaching skills and interest in teaching at this level. These lectures would present a cohesive, interdisciplinary, carefully sequenced body of scientific knowledge."

I considered this last idea to be the most important part of that summer institute. This part was intended to deepen the understanding and feeling of confidence of the teachers in the subject matter they were dealing with. We concentrated on two key words: If we could increase the teachers' *confidence* and *competence* with the subject matter, we would have achieved a lot. But that was only half of the course. In addition, exciting guest lecturers were going to present highlights of current research. These might be called inspirational lectures. But afternoons were to be spent on specially designed laboratory projects which the teachers could take back to the classroom to offer to their students. This was the sugar coating for the morning part; to give these teachers something they could really take back to the classroom so that they would feel that the institute pumped up their teaching in an actual day-to-day way. These lab sessions would also review fundamental laboratory techniques and present an overview of resources and materials appropriate for junior high school classrooms, including computer software. And then, we had a program for testing how these things went the next year.

But I want to conclude this discussion about this proposal by returning to our philosophy. Here I'm trying to tell you what I think we should be trying to accomplish at this level. We put aside the natural reflex tendency to move toward a three-year, tightly structured course at the middle school level built around a specified syllabus of topics to be covered and enforced by an achievement exam that tries to investigate the teacher's success in conveying acquaintance with prescribed topics.

Instead, we try to prepare the teacher to encourage student inquisitiveness, exercise of judgment, determination of relevance, and desire to learn more. The junior high school teacher who can do this for most of the students will have accomplished much more than can be measured by any statewide or national test yet written. These students will be ready and eager to move on to science classes at a more mature level, where the systematic and efficient textbook approach to science teaching can be used. That's what we had in mind. That's what we wanted to try to do.

What actually happened? Well, in the first place, because of inescapable but unfortunate delays in the process of winning our grant, we found out that we had permission to go ahead from NSF rather late in the spring. And the upshot of this was that we didn't have the opportunity to select from a fairly large number of applicants to obtain a middle cut of teachers, that was our intent—not to get the very best, the ones with the best preparation, nor the ones who are in most desperate shape, but the middle cut. We wanted to find out where the middle is, in terms of preparation. We didn't get that option. Instead, we took most of the people who applied. And I suspect that the outcome meant that we had a cross-section and of course there's some value in that. But it made it more difficult for us.

The first thing we learned was the obvious thing. The teachers were in a state of euphoria over the whole experience. They were thrilled to come to a place like Berkeley to hear university professors talking to them with real respect and concern about their problems and interests and, of course, also to get some new experiences they could take back to use in their classrooms. Oh, and incidentally, there was remuneration. We paid these people to come. We didn't ask that their district or that they themselves pay out of their own pocket. We let them know that we were pleased to have them come and receive a normal professional remuneration for doing something in the service of the profession.

In any event, I think that they were so euphoric that they were uncritical, and it was difficult to learn by asking them whether we were doing the right thing. And I will say in summary that in the afternoons I think we did just the right thing. In the mornings, when we had lectures by university professors, I think we got a comeuppance.

Now, you must remember that all of the lectures were selected because they were very good and were of significant concern for this particular group of teachers. What we found was this. First, the biology lectures, entirely descriptive material, all on the central nervous system and beautifully presented by Marian Diamond, went over like gangbusters. They really loved this. In particular, this is the area in which they felt most comfortable. It was purely descriptive and it dealt with physiology. This was subject matter they felt comfortable with.

Next on this list—this is not the sequence in which we presented things, but I'm putting these in a hierarchical list going downward in success. Physics was next most successful and the question is why? My goodness, this is the most mathematical and most quantitative. I think the reason is because physics is authoritarian, it's doctrinaire and it's deductive. You just have a bunch of rules that somebody on high tells you and you follow the rules and nature behaves. If Einstein said that

$E = mc^2$, it's got to be, and the only important thing is to get nature to show that it's listening to Einstein.

Well, what about chemistry? Well, I tried to present chemistry as an experimental and analytical science. I tried to get the people to think about the concepts that they are teaching. To my dismay, there were two outcomes. First, they seemed to find chemistry the most difficult subject they were confronted with. And number two, they thought the textbook was far too difficult. The textbook was *ChemStudy*, the high school textbook. Now, it may be that some of the people who said that the textbook was too difficult did not realize that we had selected the textbook to add to the depth of their understanding. But in any event, the suggestion was made by several of these teachers that we should change the textbook to something easier. That really threw me, that middle school science teachers found a high school textbook too difficult!

Let me give you one example of the kinds of things that we did and the response that we got from some of the teachers. We felt that temperature measurement was an important concept to introduce at the middle school level. This would give the students an opportunity to make measurements and to do something quantitative and, hopefully, understand the concept better. With that in mind, we rejected the computer-based approach. It turns out that some computer companies sell things called thermoprobes, complete with a little PC and a color printout. As you put the thermoprobe into a sample whose temperature is changing, you see an automatic graph drawn that shows a temperature–vs–time plot and records the temperature to five significant figures. In my view, by using this system you can avoid all of the purposes of the experiment, which are to have the students understand conceptually what they're doing, to collect the information in the form of measured data, and then to manipulate it.

That's what we didn't do. What we did instead, both in the laboratory and in lecture demonstration, was have the teachers make thermometers. They made thermometers from small Erlenmeyer flasks, filling one with water and another with mercury. Then a tube is added with a tight stopper. Now you could immerse this homemade thermometer in a temperature bath, watch the level and make measurements on it. Then we added a third thermometer, full of gas, of course with a manometer to close the system. Next, we divided the class into three sections. One section worked only with the water thermometer, one with the mercury, and one with the gas thermometer.

First, each individual calibrated their thermometer at two common reference points, the freezing point of water and the boiling point of ethanol. There were two reasons for picking ethanol. One was to awaken them to the fact that it's an arbitrary decision how you calibrate a thermometer. More important, we wanted to use water as one of the thermometer liquids, so we couldn't calibrate it at its boiling point. So, two different points, and each with a pedagogical value to it.

To return to the experiment, each group calibrated one of the three thermometers and then proceeded to measure an intermediate temperature, a bath of water at room temperature. This permitted them to establish a scale—0 to 100—from the ice point to boiling point of alcohol—100 equal spaces—so they could assign a temperature to room temperature. And of course we had each one of these three groups use the same bath so they all knew they were measuring the same temperature.

First thing they did was by groups decide what's the answer, and of course immediately they are confronted with uncertainty because they didn't all get the same answer. Each teacher got his or her slightly different personalized answer and the group had to cope with uncertainty. So by the time the three groups came together as a class and compared results, each group had a plus or minus on their answer. What they discovered then was that the people who measured the temperature with mercury got 19.5 degrees, plus or minus let's say half a degree; the ones who measured it with the gas thermometer got 20.5, plus or minus three-tenths of a degree, different from the mercury thermometer and outside of the uncertainty limits. But the third group with the water thermometer temperature got 6.6 degrees, plus or minus about one degree.

Immediately, the question is what's the significance of that big difference from the other two thermometers. Of course this reached the purpose of the experiment—to show what the concept of temperature is all about and how we measure it. How do we decide which one of these thermometers is right? Well let me tell you the teachers' response to that experiment. For many teachers, it was very unwelcome news that you get a different temperature with a different thermometer. That was by no means something that was greeted with great joy. They decided that chemistry is difficult.

I conclude that what we learned about this experience, is that these middle school teachers do have grave needs of depth and understanding of the science that they are trying to teach. That's why I think we should target our efforts toward this group of teachers. It's the highest leverage opportunity we have and we should concentrate on the content, the subject matter they have to deal with. That may be controversial to many of you who feel it's how you teach and how attentive you are to the student's development. But I don't think that's where the teacher's weakness is. I think the weakness is the teacher's *confidence* and *competence* with the subject matter. Anyway, I want to thank you all for letting me come today. I appreciate it; you're working in a very good cause. Thank you very much.

Patricia A. Graham, *Dean, Harvard Graduate School of Education*

— on producing "curriculum-proof" teachers

My co-author, Michael Fultz, and I took the title of "Curriculum-Proof Teachers in Science Education" from our discussions about teacher-proof curriculum. Both of us appreciate enormously the enduring legacy in science education bequeathed to us by Fletcher Watson who was professor of science education at Harvard for a good many years.

Let me begin by reflecting on our perspective on teachers in science education. First, we believe that the excellent preparation of teachers is a necessary but not a sufficient condition for teacher effectiveness. In fact, the brunt of our argument is that preparation by itself is not the determining variable in teacher effectiveness in science or in any other field. We make this argument despite the fact that both of us are affiliated with a school of education and schools of education have traditionally argued, and states have agreed with them, that attendance in education courses was required for prospective teachers. We do not demean the significance of importance of academic work in education. In fact, we believe that improved pedagogical effectiveness is absolutely essential for teachers. But all of us undoubtedly recall teachers who knew their subject well but who were incapable of communicating its mysteries. Our argument is that without improved working conditions for teachers, without more able and diverse people entering the teaching ranks, and without community consensus about the academic goals of education, teacher preparation—no matter how marvelous—is inadequate to ensure teacher effectiveness. Thus, those of us who seek better teaching in science and in other fields must simultaneously address four issues: (1) working conditions; (2) more diverse and nontraditional people entering the teaching field; (3) preparation and certification; and (4) community consensus.

Second, we focus on teachers generally since the issues that affect science teachers similarly affect other teachers; but there are two principal differences that are salient to science instruction. First, science teachers have more opportunities to leave teaching for lucrative positions outside education than do most other teachers; hence, the issue of attracting and retaining able persons to science teaching is especially critical. Second, (this is a point that George Pimentel mentioned as well) science, particularly in the high school, often has been oriented to the able student, not the average one. But present critiques of education in the United States have emphasized the inadequacies of instruction to and learning by the average student. For science teachers who have frequently found their most stimulating students in their college-bound classes, this new requirement to attend to the educational needs of nonscience-oriented students is especially difficult. If science teachers are to work effectively with these other students, much more attention needs to be given to pedagogy, and full and unqualified support for their endeavor will be needed that has either been ambiguous or lacking in the past.

Let me go over the central arguments. The first deals with the notion of crisis in the schools, another point that George Pimentel addressed. There is public crisis right now about education and those of us who are concerned with education are wise to get on the bandwagon. Yes there is a crisis, and we should improve science teaching in schools. Of course I will take the pledge for the need for improvement in the schools. But we also must recognize that the learning conditions of children in our schools today are significantly improved over those in the past and that one of the reasons that the critique is so intense is that the public is vastly better educated now than it used to be and can take us educators on much better. For example, in 1950, only 6% of American adults were college graduates; today the figure is well over a third. In 1950, only 18% of American adults were high school graduates; today, 70%. That means that in 1950 most people felt ill at ease criticizing what went on in the high schools. Now most people feel very much at ease in criticizing an institution with which they have had experience.

Let me give another example, one from National Assessment of Educational Progress (NAEP) data. NAEP has now been operating since 1971 and recently published the first data I have seen that show student performance over time—that is, data for 9-year-olds, 13-year-olds, and 17-year-olds in a range of subjects since 1971. The single finding that seems most important is that there is no test score for 1985 that is lower than it was in 1971. Every score is up. Does that mean we can sit back and say that everything is fine? Absolutely not, but in the midst of this perception of crisis, we must remember that we have been doing some things not so badly. The student group that seems to be most in need of attention is not the gifted/talented or the academically able or the group at the bottom, whose needs are now being addressed more satisfactorily than they were 25 or 50 years ago. Rather, it's what I call the majority in the middle. When Jerry Zacharias talks about the majority in the middle, he says it's 80%. Whether it's the 80% majority in the middle or whether it is some smaller fraction, it is those in the middle. When I say middle, I am using that term in two ways. One is the middle of what we might think of as an academic distribution in terms of achievement, but also in terms of age because again I agree with the notion of putting the emphasis on the middle school. The evidence is that the primary schools and the lower elementary youngsters are doing quite well, even the ones in the middle there. But it is the distribution in the middle, not those who adjust easily to school, but those who are just sort of there—they are the ones for whom the greatest problems exist.

We need to talk first of all about working conditions. As presently defined for teachers, working conditions are intolerable. Nobody can be expected to do well with the working conditions that we now face, and I include salary among those conditions. My irresponsible, one-line solution to the working condition problem is to have all administrators in each school district teach at least one class a day.

Second, we need to forget about recruiting the ex-milkmaids who used to populate our classroom and whom we still look to as a primary source of new teachers. By this I mean young women, like me, who grow up in the middle west, go to college, get engaged or married and realize that teaching will work out well with family life and hence go into teaching. We need people who have had greater experience with the real world, particularly people who have had experience working in fields in which they have used science, technology, and mathematics; people who say to a classroom of uninterested eight graders why it is useful to know mathematics. We need to recruit more of those nontraditional people to our classrooms.

At Harvard we are now in our fourth year of a program of mid-career math-science teachers for whom the average age is somewhere in the 50s. The program is limited to 20 people a year, and last year we had 600 applicants. Their average score on the GRE quantitative puts them in the top 90th percentile. These are intelligent people who look forward to teaching math and science in grades five through twelve and who are doing so on the basis of the evidence thus far. I am also enthusiastic about the prospects of a teaching career for the idealistic undergraduate biology major who is undecided between going to medical school, earning a Ph.D. in biochemistry, or something else. Let that youngster teach in the schools for three to five years with a little preparation while he or she decides what to do next. We need to give them some preparation, but we need to make it much easier for undergraduates to go into public school teaching for a brief time. In an earlier era, families sent their children who had completed their studies for a "wanderjahr" in Europe. Why not have them spend that year in the public schools at public expense?

In the area of preparation and certification I agree vigorously with the argument for competence and confidence made earlier. Our paper contains a nice quotation from Robert Apfel, from the mechanical engineering department at Yale, who talks about how science might be taught better at the elementary level.

Finally, without community consensus on academic goals, all of our efforts will be lost. We have an urgent and desperate need to make our case to the public that the needs of our society in the future are for all of our citizens to be well-educated and that we can deliver on that mission.

Neither we nor the public have made that case sufficiently yet. Sometimes we educators have not made it because we have been afraid that perhaps we could not deliver with all the students. But that is our task, and therefore we must.

In conclusion, we would argue that the basic task of teachers is to nurture and to enhance the wit and the character of the young. Few adult jobs are more challenging or more important than that. Hence, we can be cautiously optimistic about the willingness of society to accept the necessity to change teachers' working conditions, to encourage able people, both traditional and nontraditional, to teach, to urge colleges and universities to help teachers become truly pedagogically effective, thus justifying a change from a bad idea—the old child-centered school—to a new, good idea—teacher-centered schools with the obligation of the teacher to enhance the learning of all the children.

Pamela Surko, *Member of the Technical Staff, AT&T Bell Laboratories, and President, Association of Women in Science*

— on science teaching in a technological world

I'm going to talk about what I would like to see school science bring to artificial intelligence (AI). After that, I'll talk a little bit about what we're bringing to you.

I really feel strongly that the best preparation for work with AI is math, math, and math. What I discovered when I came into this field from another field—physics—was that my math background was inadequate. Can you believe that? I have a Ph.D. in physics and I didn't know enough math. And the surprising thing was that a lot of the math I needed I could have learned in middle school.

The other thing we really need is those creative problem- solving abilities. Not only, once given a problem, knowing how to go about deciding how to solve it, but the harder skill: given a murky situation, knowing what's a good question to ask, and *then* knowing how to find the answer. Those things typically come out of the math classes.

Communications skills are very important to AI because part of the business of building expert systems is interviewing experts, talking to people, communicating. And if you're a software engineer, you certainly have to be somebody who can work in a group.

I put computer awareness last, and you may find that a little bit surprising, but the other things are so much more important. The fact that we do have more computer awareness in our schools is very good and I am really glad to see it. But if I had to give up the problem-solving skills or some of the math in order to get computer awareness, I would give the computer awareness away.

Here's what I mean by broad math background, and this is just my own view of what I've needed to do my job. First of all, we need the number crunching stuff—arithmetic—and then the abstractions—the algebra, the calculus, the geometry—plane geometry and solid geometry. I need a lot of set theory, particularly axiomatic set theory and I'm old enough so I didn't get it in middle school. My kids did get at least some. What I didn't see my children getting (they've just recently graduated from high school now, so they went through middle school some four or so years ago) was any graph theory, they didn't get any logic, and they only got a few days of probability theory. Those are all things that I really need in my work and it was somewhat embarrassing to have to go back and learn things that I really could have learned at the middle school level. I'm not talking about really sophisticated, graduate level mathematics here. I'm talking about the general introduction. And a lot of these concepts are non-numerical, and they can be taught at almost any grade level at some level of sophistication, as you folks know.

Of course, I have to put in the statement that since math, math, math is so important, the fact that we're turning people off—both boys and girls, of course, but particularly girls, in the middle school—I really worry about that a lot. And I also know from talking to educators, at least in the state of New Jersey, that it's not all the educators' fault, it's a societal influence. In some cases, you have to overcome the effects of the parents. In particular, the number of women engineers now is only a few percent. And certainly I think that half the bright people who could be engineers are female. Ditto for minorities.

I wanted to say a few things about computer awareness too. I'm really glad to see computers in the classroom, but I would really like to emphasize that they should be there to teach the reasoning skills—to be used as a tool rather than an end in itself. It's not important to teach the young child all the ins and outs of the syntax of BASIC or UNIX or MS-DOS. The languages and operating systems come and go. Every project I do I learn at least one computer language. Once you've learned one, it's not hard to learn another. Syntax is trivial because it doesn't require any deep thought. It just requires remembering. What's really important is to teach those children how to consider a problem at various levels of abstraction: to make chains of reasoning ever more and more complicated. I've never used Logo in a classroom situation, but I did watch some kids using it once and I thought that the session seemed to be teaching them exactly the kinds of things that I thought that they needed to know.

Since software engineering is a teamwork effort, this seems like an ideal place to bring teamwork into the schools. There are very few places where you get a chance to do a project in a team. At least that was true in my kids' education. And this is an ideal place, particularly if your computers tend to be scarce resources anyway. Sit two or three kids down in front of a terminal and have them solve a problem together. I just want to make one parenthetical comment about the role of games in classrooms. I'm glad to see some games in classrooms. It's nice to have people introduced to computers in a very non-threatening way and it's nice that the computer is a reward for doing other work well, but we do have to be a bit careful with our choice of games. Because if a little fourth grade girl doesn't enjoy clubbing trolls over the head, then we don't want to give her the message that she doesn't enjoy computers. And a child who doesn't have good eye-hand coordination shouldn't feel that he can't succeed with computers. We have to be really careful when choosing games that we're not rewarding just aggression and eye-hand coordination. As someone who doesn't enjoy clubbing trolls and who has rotten eye-hand coordination, I'm still a very good software engineer. You really don't need either of those skills.

I must say, by the way, that of the arcade-type games, Pac-Man is probably about the best from the point of view of aggression. It seems that the kids view it more like eating popcorn and that little thing that's going along doing the munching doesn't really seem to have any gender, independent of whether it's Ms. Pac-Man or Pac-Man.

Now I get to my other topic: what AI should be bringing to school science. A lot of what's already in the classroom is really great stuff. There is some of it that is already artificial intelligence. Much of it is not. That doesn't mean it's not good. Artificial intelligence is a technology that requires a lot of computer cycles. It's expensive. So if you can do whatever you want to do without it, you should, if you want the biggest bang for your bucks.

The kinds of things that are in most classrooms today are what I would call adaptive systems. That is, the computer administers a pre-test to the student. There are maybe a half a dozen different choices at that point based on what the child does on that pre-test, and so then there are canned sets of instructional material and drill based on the pre-test, and then the child takes a post-test. So, it's much more tailored than an individual classroom teacher could be, simply because you can go through this cycle at every small chunk in the curriculum and each one is tailored to an individual child. I consider that this is a really nice way to do drill. And it certainly is much more efficient than having the classroom teacher give one drill and then having to grade them all as well. But it isn't artificial intelligence.

Let me describe what will come. Notice that we're talking about the future tense here, and I think it's 10 to 20 years down the pike. I don't honestly know whether I'm optimistic or pessimistic. I tend to be pessimistic usually. But I think I may be optimistic in this case. What intelligent tutoring really means is that the computer program enters a dialogue with the student. The computer program knows not only the subject area that's being tutored, but, as the communications occur, builds up a model, a view of the student's current state of knowledge. It has rules in it about how to teach and it has strategies in it for how to communicate. And it's more like one-on-one tutoring than classroom drill or classroom tutoring. It's also not real easy to do and we haven't solved all the research problems yet.

I'm going to talk about each of those four areas a little bit more in detail. First, material dealing with the lesson's subject area. This one I think is probably the easiest one to actually build: knowledge about a subject area. You have a combination of "cookbook knowledge." That's not demeaning; what that means is sets of facts, the information that the student needs to acquire. Of course, they need to be organized in some reasonable way because that's part of the way we learn. And you also need what we call deep knowledge, which means the kind of reasoning that you're going to do and you want your students to learn to do, from first principles.

Now the tricky part in this business is trying to figure out whether the student's answer is really right. Here's an example. Suppose that we're talking about a tutor that's teaching somebody how to debug electrical systems and the expected response is that the resistor R1 now has infinite resistance. Suppose your student says "R1 opened." Well, now that's a fairly easy one because opened is almost a direct synonym to "infinite resistance." What it means is that somehow the resistor has fallen into two pieces and there's no electrical path at all. That means that there is infinite resistance, and so it's relatively straightforward for a tutoring system to understand that open means the same as infinite resistance.

But how about the somewhat more experienced student or creative student who says "R1 fried"? Now that's slang, but it's absolutely common slang, and it also has some more physics or electronics built into it. What fried means to this student is that, at some time in the past, that resistor got more current through it than it should have. As a consequence, it heated up so much that it actually vaporized—we say fried—and it is now open.

So what that student has done is provided more knowledge. That's actually a more sophisticated answer than just "open" or "infinite resistance," and the tutor has got to be able to understand that. One of the most difficult things to worry about in these computer programs is how not to squelch the creative. And also how not to miss the right answers that are just slightly atypical.

The next area is hard: trying to infer what the student's state of knowledge is from the conversations that are held between the student and the tutoring program. Determining exactly what the student knows and doesn't know is very difficult. The number of things that you say back and forth is relatively small. The student herself doesn't know what she doesn't know. So it's extremely difficult to decide what that frontier of knowledge is. And yet, you have to know that in order to be able to tutor effectively.

In addition, there are the other problems of unspoken questions and unspoken confusions and unspoken misconceptions. For example, a tutor is built for an airline, and it sits in a terminal and gives information. A passenger comes up and types, "Is this the gate for the flight to Atlanta?" and the tutor says, "No, you need gate 66. The flight departs at 6:35 p.m." Okay. If the answer had been "yes" to "Is this the gate to Atlanta?" then the tutor would have known that it didn't need to provide any other information. "Yes" was enough. Since "No" was the answer, the tutor understands that there are two other unspoken questions, not only "Is this the right gate?" but "If this is the wrong gate, which one is the right gate?" and "Am I in real trouble?" So it says, "The right gate is this one and go there."

That's one of the differences that you're going to see as these intelligent tutors replace the adaptive systems. An adaptive system would have had to say "No," and then the customer would have had to type, "Then what is the right gate for Atlanta?" And, of course, unspoken confusions and misconceptions are real lulus to understand because the students don't know themselves.

Here's an example of a session. This one actually happens to be a human tutor with a student who's trying to learn geography, and there are some features in here that we try to put into the intelligent tutor programs. Tutor says, "Do you think it rains much in Oregon?" and the student says "No," and the tutor says, "Why not?" and the student says, "Because all the neighboring states are dry," and the tutor says, "That's right, but you can't generalize. Actually it rains quite a lot in Oregon. Can you give a guess why?"

Let's go back to the beginning now. Tutor says, "Do you think it rains much in Oregon?" and the student says "No." If this were an adaptive system, certainly the program at this point would say, "That's wrong." This tutor, on the other hand, chooses not to rap the student on the knuckles at this point, but to interrogate a little more to find out the cause of the misconception; to try to figure out how the student's world view differs from the tutor's world view. So she says, "Why not?" And the student says, "Because the neighboring states are dry." Now, from this interchange the tutor has got to infer that the student is making a generalization and that the generalization is incorrect. The tutor at that point essentially interrupts the conversation and says, "You're wrong," and suggests something else to try that gives the student a hint: she says, "Think about mountains and oceans and things like that." It's a much more sophisticated kind of interaction than the kind of thing you can do with canned responses.

It's also nice because what you're really doing is trying to bring the student's view of the subject matter into accord with your own without stopping at every single question and making sure that the student has given the right answer. That's what human tutors do. They don't require that the answer to every question be right. They simply demand that by the time the session is finished that all of the important knowledge and reasoning strategies are correct. It's much less threatening to the student.

The next area is communication, the part of the program that does the talking with the student. It's really hard to understand what the student is saying.

This is the standard example for why natural language parsing and understanding is really hard. Here's a sentence: Time flies like an arrow. You are now going to write a computer program that's going to understand that. Well, that's not too bad. It's a little poetic, but it's a very simple sentence grammatically and you know that any understanding program you have has got to have all the rhetorical devices built in: simile, metaphor, and all that sort of thing.

Here's another sentence. Fruit flies like an apple. Okay? There's a whole lot of ambiguity in natural language and a whole lot of context that comes from common sense. This does not mean that fruit takes wing like an apple, this means that if you look on old apples, you're going to find fruit flies. And *flies* is not a verb here although it was a verb in the first sentence, and *like* is a verb here and it wasn't a verb in the sentence. It's not as easy as you think to understand the meaning of natural language, even though it's fairly easy to figure out what most of the parts of speech are.

Here's another example of why it's hard to deal with natural language. This one's a really easy sentence: I dropped an egg on the floor and it broke. What does *it* refer to? Does it refer to the egg or the floor? You all knew that it referred to the egg but that's because you've got a tremendously sophisticated knowledge of strength of materials and Newton's laws of gravity. The natural language processor, if it's going to understand that sentence, has to have all that information, too. It's really hard to do natural language. And, unfortunately folks have been promising to parse natural language for lots of years, at least ten, and I think that that's going to be the limiting factor on getting tutors that work. There are strategies for making intelligent tutors that don't require natural language, that is, things where you give students menus—you know, choices of this and that— but then it tends to get very fragmented again, and it's really not the kind of intelligent tutoring that you want.

Another thing an intelligent tutor has to have in it is the strategies of how to teach: how to decide what the appropriate issues are in a particular domain and how to focus on them effectively; the level of discourse; the level of abstraction vs. detail; the level of sophistication that you need for this particular student; various teaching strategies; Socratic method; entrapment. (You keep a student on a line of reasoning until he reaches a conclusion he knows is wrong, in order to demonstrate that a hypothesis was wrong back at the beginning.) Even simple matters, like when to interrupt to say, "No, you're wrong," when to repeat material, all that has to be built into an intelligent tutor.

I think, by the way, that one of the fringe benefits that's going to come out of intelligent tutoring is the fact that we will have to put teaching under a microscope. Computers are really very demanding; absolutely every last detail has to be investigated in order to make a program that works. That means that we're going to need the kind of scrutiny on how to teach that perhaps hasn't existed.

Here's what I think the prospects for intelligent tutors are. I think, of course, that there will be a gradual phasing of the computer-aided instruction you see now, which is by and large adaptive, into more and more intelligent kinds of tutors. The high-powered ones are, I am sure, ten years away and my guess is probably they're 20. One of the things you might like to know is, what's the quality of these things going to be like? Are they likely to be really useful and are they going to supplant the classroom teacher?

If I look at the way expert systems have permeated the market, I think what we will probably find is something very similar to that. That is, the quality of these things tend to be high, and they tend to be relatively expensive, but usually the market can bear it. They're doing a job that's so expensive to do anyway that it doesn't matter that they cost a bit.

Let me explain to you why expert systems quality is high at Bell Labs. For the expert systems we build, we interview two or three of the very best cable experts in the United States, and we really interview the daylights out of those poor folks. By the time it's done, we've done a reasonably good job of capturing a tremendous amount of their knowledge.

Now, our program doesn't do as well as they do, but our program does better than the average cable analyst in the telephone companies, and I think that's probably what's going to happen with intelligent tutors. People will work very hard with absolutely the very best teachers in the United States and the quality of the resulting products will probably be such that they will do about as well as the average teacher. They won't do as well as the teachers that taught the tutors, but they will do fairly well.

Now what I really hope is that there will be hundreds of companies building intelligent tutors, and that you have 70 or 80 different programs to choose from when it's time to make a purchase. I really hope that school districts buy from a lot of different companies, because one thing I really worry about is having one intelligent tutor program become ubiquitous. Because suppose there's a subtle bias in this program and it squelches a particular kind of creativity? Well, of course, human tutors will tend to squelch certain kinds of creativity; depending on your personality you either encourage or don't encourage certain kinds of creativity. But I really don't want the child who might be discouraged for one year by one human being discouraged instead for eight years running because the same program is in all his classrooms for his entire years of school. I really hope that we have lots and lots of these things, and also that school districts buy lots and lots of different kinds of them.

Very quickly, just a little bit about expert systems. These are already here and are coming onto the marketplace now. They're easier to do than intelligent tutors. What you take is a small area of expertise and model it as "if this, then do that" kinds of rules that replicate an expert's performance in a very limited area. Because they're coming into popularity in almost every area of the marketplace, I can't imagine that they wouldn't be coming in education as well. Here are some thoughts about where you could use them.

I was just talking to someone from the New Jersey Education Association who was telling me about a wonderful new program called "Art and Mathematics." It's designed to teach certain spatial relationship skills in the art classroom that are necessary before you start doing plane geometry. The question is, at what level should this be done, and does a particular group of students need it? The person spent a couple days studying test results and decided that yes, it was good for this particular age group.

Now, that kind of sophisticated analysis of a test is something that an expert system could do. Give it a question and it will go look at the data base and understand how to get the data out, and it understands how to do all the queries and that sort of thing. There are lots of opportunities for use in classroom administration. Anytime you have a human being sitting down with a lot of paper on their desk, probably that's a candidate for an expert system. There may be better ways to schedule classrooms, schedule exams, or get kids' junior high school schedules straightened out. There are algorithms for doing this in part, but the true optimization problem is a real lulu and it would be amenable to expert systems.

I think what's going to be really nice are some of the fringe benefits of AI research, because much of AI research is linked to cognitive psychology. One of the ways to make a program do something interesting is to try to figure out how humans do it, so we're very closely linked to cognitive psychology. We also have the advantage of being glamorous and well-funded, so there might be some very good spill-over. Another thing is that in building an expert system, just the very fact that you have to sit down and evaluate a particular task such as teaching in such a very detailed way is bound to have—we've already found that it does have—positive benefits, even if you never build the expert system. The fact that you sat down and learned more about the domain than you ever have before and codified it—put it down in a well-organized fashion—that in itself is a tremendous benefit. We've seen that already in medical diagnostic expert systems; more is understood now about how good diagnosticians diagnose than before, and I think that the same thing will happen with intelligent tutoring. We may actually learn something more about how kids learn and about how good teachers teach.

Edward Harvey, *Professor of Sociology, Ontario Institute for Studies in Education*

— *a sociological perspective on teaching and the conflicting ideals of American culture*

Today you are going to get a view from outside—outside in terms of the discipline, because I am a sociologist, not a science educator, and also outside of the country, because I am from Canada. I hope that the externality of my comments will add to their interest and provocativeness.

The reality is that we are living today in an age of change. One of the best books to come along in recent years is Robert Wright's seminal work, *The Next American Frontier*. It states clearly and straightforwardly that the great engine of American economic growth—standardized mass production—has come to an end. The future belongs to high technology, flexibility, creative teams. International competition has never been tougher. Sometime in the next five years the Japanese will account for over 50% of all automotive production in the world. That used to be the very backbone of the American economy. Our political leaders realize these problems, although perhaps they don't always respond to them as quickly as we might wish.

There is a general level of concern in your nation today, as there is in ours, about how we are going to respond to these new pressures of technology, international competition and associated patterns. Part of this anxiety, part of this search for solutions ramifies into education, particularly science education, because science education is so fundamental, so central, and so critical to developing a society that can be internationally competitive and technologically at the cutting edge.

We know that there is much gloomy news out there, that U.S. students are learning less and learning what they do learn less well; and the question is what to do about this. I would like to offer some comments in three broad issue areas. First, to what extent is science teaching a profession or to what extent should it become more of a profession? Second, what are some of the principal debates on science education in the United States today. Third, what's the future for science education?

As we know, there have been a number of recent reports, such as *A Nation at Risk* and reports from other influential groups, that have raised important questions about the quality of school teaching in America, and, in particular, science teaching. Paul E. Peterson of the Brookings Institution, who is also participating in this conference, has commented that with some exceptions these various studies do not really address the most difficult conceptual and political issues.

We agree with Peterson's criticisms. In particular, we think that there are two issues that need to be addressed in conceptual terms, notwithstanding the general absence in these reports of practical and concrete recommendations about how to improve science teaching. The conceptual problems are the proper historical and cultural context of teaching and the school system in America, and the need to analyze the occupational structure of teaching in America.

On the first issue, an analysis of the teaching occupation shows a major contradiction in the objectives bestowed on the public school system in American society. That contradiction is between the production of excellence on the one hand, and the mass production of social mobility and open, equal opportunity on the other. That contradiction is at the heart of the debate about science education.

Let me quote from the recent report of the National Science Board Commission: "By 1995, the nation must provide for all its youth the level of mathematics, science, and technology education that is the finest in the world without sacrificing the American birthright of personal choice, equity, and opportunity." In our view, such objectives beg the questions not only of how so much is to be achieved, as Peterson points out, but the dynamics of a class divided society that wants a technocratic elite. The commission says, "Excellence and elitism are not synonymous," and then, to put it charitably, it buries its head in the sand.

The second issue relates to the question of whether or not the needs of science education would be well served if teaching and teachers were to become more professionalized.

Now, is teaching a profession? Quite literally, that question has dominated the literature on studies of teaching and education in the United States since the 19th century. It's an important question not so much because of the content of teaching as because of the community appreciation of this term "professional."

In the United States being called a professional evokes high status for the occupational group so labeled and high esteem for the individual who approaches work professionally, no matter what the occupation. The idea of being able to combine service to the community and success in one's personal life is the quintessence of a profession. In short, being or becoming a professional is inextricably linked to the American ideals of democracy and social mobility.

As we have pointed out in our paper, there are various models or ways of analyzing and assessing when an occupation is a profession and when it is not. One of the influential models of what constitutes a professional occupation is called the trait model. It looks at a variety of things—for example, an abstract body of theory or esoteric knowledge upon which the practice of the occupation is based; a long period of training, typically in a university, through which this expertise is acquired; the ideal of service to the community; certification and practice procedures and guidelines that are established by the profession itself; and an enormous amount of autonomy in determining how the profession will go about its work and police itself.

This kind of freedom and individuality, which characterizes the classic professions like medicine and law, is the antithesis of bureaucratic jobs or bureaucratically regulated employment. We all know what bureaucracy is, especially if we're from Washington, and although bureaucracy is an efficient way of socially organizing work, it is not personal or individualistic—elements that are very much central to the concept of the professions.

In terms of the trait model, teaching doesn't have all the traits and is an occupation that in recent years has become increasingly bureaucratized. In this sense, it is at best a semiprofession.

Another focus is who controls the relationship between the professional and the client. Once again, if we examine teaching, we find that much of the way in which teachers carry out their mission is, in fact, determined by others: by school boards, by departments of education, or by other external authorities. So, although it is true that a teacher has a certain moral authority and a certain autonomy within the setting of the classroom, that moral authority and autonomy are confined to narrow channels compared with some of the more powerful, traditionally established professions.

Nevertheless, teaching as an occupation has provided an opportunity for many people to move upward socially. In the United States the professions are generally highly regarded. They are specialized enclaves of excellence and expertise and are at the top of the social ladder. So, it's hardly surprising that teachers seek to advance their occupational interests in terms of this professional model. As Albert Shanker, president of the American Federation of Teachers, recently stated,

> bright young college students are not going to come into our schools to teach unless they are treated as professionals. If we are to achieve that professionalism we have to take a step beyond collective bargaining. Not to abandon it, but to build on it. To develop new processes, new institutions, new procedures which will bring us what teachers want in addition to what we get from collective bargaining—to wit, status, dignity, a voice in professional matters, and the compensation of a professional.

Let me try to sum up this debate on professionalism. It's our argument that in the various reports to which I've alluded —the foundation report, *A Nation at Risk*, and so on—the central contradictions between excellence in mathematics and science education and the American birthright for mobility and opportunity have not been faced either in the recommendations for teacher training or in the analysis of teachers as a professional group. Through our analysis of the different models of the professions in America we have focused on several matters that are central to the current debate.

First, there's no such thing as a profession in any fixed way, only as an occupational group in relationship to other groups. In addition, the central dilemma facing science teachers and all teachers is the same as the central contradiction of American society: The unresolved desire to be both equal and excellent, to be open to everyone and to still produce the best. How to accomplish these goals has not been examined, but has been thrust upon the educational system without the provision of the resources or autonomy necessary to do it.

Are teachers professionals? We conclude that it is neither here nor there whether teachers are professionals. They are a strongly organized, powerful group rendering an essential service that lies at the heart of a democratic society. The current priority put on becoming more professional by the teachers' unions is more of a labor market strategy and a desire for increased power than a useful means of resolving the reforms of education for the 21st century and the post-industrial age.

Now I would like to comment on our concerns regarding the debates on science education. *A Nation at Risk* and some of the other reports are written in highly dramatic language, evoking feelings of nationalism and international competitiveness. The language of the reports, and their recommendations for better mathematics and science education for all American students, seem to be a call to national unity and mobilization rather than recommendations for implementation.

Another report, *The Nation Responds*, takes a quite different approach, emphasizing the national will, the funding commitments, and the state-by-state efforts at reform. There is a serious disjunction here. *A Nation at Risk* argues the need for better citizens to preserve democracy and world leadership. *The Nation Responds* calls for better communicators, scientists and technologists, in order to be more competitive in a world where, as the report says, there is a redistribu[illegible] trained capability throughout the globe.

For scientists, especially, the spread of ideas through mathematics and international science is crucial. Most are aware that national complacency has sidetracked entire civilizations in terms of science development, but, as its critics have pointed out, organizational innovation does not characterize *The Nation Responds* any more than it did *A Nation at Risk*.

There is a lack of clarity in the objectives of science education. Robert Yager, for example, has defined the domain of science education in terms of an increased focus on the interrelationships between science and society. He argues that focusing science teaching and science education research on the science/society interface clarifies the objectives of the discipline. It does this by providing a rationale for and a coherence to research, curriculum, and instruction that are lacking in the more restrictive definitions. Moreover, Yager jargues that the definition accommodates the dynamics of a changing science and its impact on society, as well as a changing society and its impact on science. This view takes the position that there is a distinct body of knowledge that encompasses aspects of the social sciences and the physical sciences that define a science education field.

Now, the critics say that this is a soft definition, because it permits an inordinate amount of influence on science curriculum development by nonscientists, and therefore a loss of technical excellence. These critics suggest that science education does not yet exist as a definable body of knowledge. The implication is that real or pure science needs to be taught in science classes not something called science education.

This debate between science and society and pure science education in the schools reflects the more general American debate about excellence and equality. The recommendations made by the various reports, most particularly the National Science Board and *A Nation at Risk*, essentially suggest that science teaching should return to the basics—it should be taught by teachers who have been separated out from other teachers by their training, salaries, and working conditions. In other words, there should be an elite group of teachers in mathematics and science.

In short, while eschewing elitism, the recommendations of the authors of these reports seem to suggest that the creation of an elite teaching corps is the only way to achieve excellence. The creation of a teaching elite by no means implies that every American school child will have a good education in mathematics and science throughout the school years.

Another critically important issue is the matter of whether or not you can retrain science teachers who are presently underutilized in order to address the current imbalance in the supply and demand. In my experience with one program, 95% of the people who were interested in becoming involved in the program were not sufficiently up to speed in their disciplines, in effect, they would have had to retake a significant part of their undergraduate education just to be up to speed in these quickly changing disciplines. So the notion of achieving a quick fix through retraining does not appear to hold water in light of the available data.

What are some directions for us to go in the future? Several of the reports emphasize singling out science teachers for special attention or benefits that will further professionalize science teachers and improve their classroom performance. While unquestionably these increased pay and benefits would be highly acceptable, they will not lead to a breakdown of the occupational solidarity and collective bargaining, because the social organization of teaching, as we have documented in our paper (in this volume) is quite different from that which characterizes the free professions. It is also quite different from the social organizational characteristics of those working in industry or elsewhere. Finally, the call for more cooperative programs involving education and industry would clearly challenge the professional association boundaries. In short, there are many serious, significant institutional barriers to the achievement of some of these new directions. However, if the objective is to get a more knowledgeable, competitive work force in place by 1995, such challenges to entrenched institutional boundaries are required.

To sum up, we have raised questions concerning the values and the organizational arrangements of science instruction in North America. There is no question that considerable resistance will be encountered by established interests in any attempt to change the nature of what is done by working teachers. Simply instituting changes or improvements that answer today's questions will not answer tomorrow's. We don't just need more scientists or students who know more science. We need a closer link among the producers and consumers of science knowledge, and its use in technology and technical fields.

Eric Bloch, *Director, National Science Foundation*

— on the efforts of the National Science Foundation to contribute to the maintenance of a qualified science teaching force

I'm glad to have been invited to your first National Forum. I hope you will be successful in establishing these forums on an annual basis because I believe that these meetings can play a very important role in improving science education by focusing attention on major issues and by bringing together people with diverse experiences and various points of view.

I'm particularly delighted to have an opportunity to talk about the problems of teaching science in the schools, to share my perspective with you in that regard, and to describe what the National Science Foundation is doing in this area. We have a very important role in dealing with these issues, but it's a modest one.

I have been asked to address the competition between industry and the schools for technically trained people, and I do have some ideas about that topic; but I would like to begin by outlining why the quality of science teaching in the elementary and secondary schools is of critical importance and what NSF is doing to improve it.

For many decades, writers of science fiction have attempted to describe a faraway time called the 21st century. I'm probably not the first one nor will I be the last one to observe that the 21st century is already upon us. We only need to realize that children born today will be in high school in the year 2000. Many of their views about science, about mathematics, about technology as well as their basic competencies in these subjects, in these fields will have been formed by that time. We owe it to them and we owe it to ourselves to be thinking about the quality of their science education right now. The world they will grow up in and continue to live in as adults will be even more complex and more competitive than the world of today.

The signs of fundamental changes are all around us. The most striking and pervasive change of the 1980s—one that is fundamental and irreversible—is the shift to a global economy. The new world economy features sharp international competition, particularly in the areas of technology where the United States has been preeminent since World War II. I need only to mention the challenges of the past few years in the automotive industry, in consumer electronics, and of late, if you read the papers, in the semiconductor industry.

The success of some of our trading partners has had a very rapid and sweeping effect on our industrial base. Not only Japan and now South Korea, but in the near future, probably Brazil, India, and China are all aspiring to play a major role in specific areas of technology by the end of this century.

While these other nations have strong advantages in world competition that are not easy for us to overcome—like cheap labor, lower interest rates, and so forth—I think the United States has two clear advantages in international competition: First, the flow of fresh ideas and discoveries from researchers in universities, companies, and government agencies; second, the large, diverse, well-educated work force through which entrepreneurs can capitalize on those discoveries to create new technologies. The *only* way that we can keep ahead of other countries is by continuing to have the best technically trained work force, the most inventive and adaptable one in the world, to pursue the research and innovation that we have shown in the past and translate it into products in the marketplace.

That's the first reason why I believe that a good education in the sciences and mathematics is so important for our secondary and elementary school students. Whether we are considering the relatively small number who go on to become scientists, engineers, or medical doctors or the larger numbers that will hold such 21st century jobs as laser technicians or genetic technicians, all must be adequately prepared by our schools to further their scientific and technical education. The nation is also dealing with tough public policy issues that require a fair degree of understanding of the science involved. Such difficult issues as toxic wastes, nuclear proliferation, and acid rain will still need to be dealt with in the 21st century. No doubt they will be joined by new issues arising from biotechnologies and from still very unknown discoveries in many other disciplines. So the second reason for strengthening science and math teaching concerns the nonscience students, the individuals that will become the lawyers, artists, homemakers, and craftsmen of the future. As citizens of a technological world and in some cases as the key decisionmakers they will also need a good science education.

Finally, and one should not undervalue this, there is the search for knowledge about the universe and some of its mysteries that drives people in all nations and centuries.

So the question then arises: Where are the 14-year-olds of the year 2000 to get this learning? Where are they to get this preparation for their 21st century work? Some small fraction will get their competence and understanding of science at home from their parents. It's always been that way, and I hope that it will always continue. Some will do a great deal of learning on their own or through television, museums, home computers, and other exposures. But most of their understanding of science will still come through interactions with their grade school and middle school teachers.

Studies have shown again and again that a student's attitudes toward science and math as well as his or her competence in technical fields are formed in the early grades. But how well prepared are the million elementary school teachers and the 200,000 secondary school math and science teachers to instill interest in these subjects and to teach in a factual and in a knowledgeable way? Fortunately, qualified, committed science and mathematics teachers can be found in schools throughout the nation and at all grade levels. Unfortunately, there are far too few of them to provide the early and repeated exposures to these fields that all of our students will need.

The 1983 report of the National Science Board Commission on Precollege Education in Mathematics concludes that top priority must be placed on retraining present teachers and recruiting new teachers and training them well so that all will be of high quality. The report went on to add that teachers must be provided with a work environment in which they can be effective.

Through this and other reports appearing almost at the same time that describe the state of the nation's educational system, the public today is becoming more aware of the need to upgrade science education in the schools. Because of this recognition, NSF has been able to develop a set of programs focused on the precollege level, particularly on helping teachers improve their subject-matter competency. In the fiscal year that is just beginning, FY 1986, the Foundation intends to spend more than $50 million on a variety of precollege science education programs. Our goals include: improving the preparation of new teachers, providing subject matter training for in-service teachers, revising instructional materials, and exploring advanced technologies that can be used to teach these subjects. I should add that we know good technologies can never replace good teachers, but they can certainly be used to increase their productivity and their effectiveness.

There are numerous opportunities that offer points of strategic entry to improve precollege science education. NSF's efforts are focused on those points where its unique strengths and leadership can have the greatest effects. All of NSF's precollege activities share certain characteristics. First, we are trying to leverage the federal dollar. Second, we are trying to share results widely. Third, obviously the projects we support must meet high standards of scientific validity. For this reason the active participation of practicing scientists and engineers is very crucial; we rely on the special linkages that exist between the National Science Foundation and these communities to make this happen and to encourage this participation.

With these ground rules, it's easily seen that NSF gives preference to projects that establish partnerships among those with interests and expertise in precollege education. Partners can include local and state education agencies, business and industry, colleges and universities, or professional societies or combinations of the above. Such partnerships are both idea-sharing and cost-sharing arrangements, and one should not differentiate between the two too much. The Foundation is committed to the partnership principle, both as evidence of local need and commitment and as a way to ensure that the impact that we have with our programs is as broad as possible.

Now I'll give a few examples of current programs. Before beginning their service, most elementary school teachers receive virtually no formal training in either how to teach mathematics and science or in the content of these subjects. That's a shocking situation, especially in this technological age. Secondary level teachers also receive far too little content training and hands-on experience. To help deal with these problems the Foundation supports the development of specialized materials and courses to help acquaint teachers with their subject areas. In addition to our customary support for unsolicited proposals, NSF will soon issue a series of formal solicitations designed to stimulate significant changes in teacher preparation.

In-service and master teachers are two other important areas. Many in-service teachers feel a great need to improve their abilities to teach modern math and science. A major element of our strategy in this area is heavy emphasis on leveraging through master teachers. In this approach we recognize outstanding teachers, provide enrichment in both content and methods, train them to assist their colleagues, and encourage their school systems to provide the support necessary to carry out this role. NSF's goal over the next five years is to influence a quarter of the nation's science and mathematics teachers either directly or through their contact with one or more master teachers.

Another aspect of science education that badly needs addressing is that of instructional materials. A variety of books, films, and hands-on materials were developed in the 1960s and 1970s, to a great extent by NSF. The content of much of this material needs to be brought up to date. We will issue shortly a special call for proposals to update elementary school science materials and also to revise mathematics programs in early grades.

The fourth and last example of the Foundation's assistance in the precollege area is our support for advanced educational technologies. Modern information technologies offer a tremendous potential for improving education. Computers are becoming universal; combined with graphic systems, video discs, and TV transmission technologies, the computer holds the promise of reducing the cost of education and greatly improving its effectiveness. Pioneering work in this area such as the development of computer languages and video disc technology for education was accomplished with Foundation support years ago. We are continuing to build on this tradition, exploring new ways, new hardware, new software, new methods, new approaches.

I believe that the Foundation has now established a set of programs that focus on the most important problems and support the highest quality projects. But the overall need is so great that these programs will never be able to address it adequately particularly in the current budgetary climate. Elementary and secondary education is principally the responsibility of some 16,000 local school districts. That is the proper place for that responsibility and where it should remain. Under the best of circumstances, the Foundation will remain a small player in terms of national funding, but I hope an influential player in terms of pointing the way, being a catalyst, being a facilitator for new ideas and for new approaches.

Now let me turn to my final topic—the competition between the schools and other sectors—notably industry—for people educated in science and technology. The question can be reformulated as follows: What can schools do to attract and keep qualified science and mathematics teachers in view of demand by industry for many of the same people? I suspect that a great many young people are attracted to teaching for its obvious satisfactions. And I know that myself since I have a daughter who is a school teacher. But many of these prospective science and math teachers are also attracted to the more direct rewards offered by industry, such as a higher salary scale and the other monetary rewards of a profit-making enterprise, opportunities to work on exciting projects with the support and resources of a large firm, or to be in on the start of a new enterprise.

It seems to me that schools must be prepared to offer three kinds of rewards if they are to attract more people with interests in math and science or keep those people. First, schools must offer a professional environment that allows good teachers to flourish and encourages their personal and professional development. That means such things as good lab equipment, smaller classes, supportive administrators, and less paper work and bureaucracy. Second, they must offer a more competitive salary scale, particularly at the entry levels for people considering which career path to take. If industry salaries are the main barriers, schools must be better prepared to meet this competition, even if that means differential salary scales for those disciplines that are in short supply. The market economy can accomplish a great deal and that statement doesn't only apply to mousetraps or refrigerators. Market forces apply to the supply and demand for skills, especially professional skills. In fact, if you look at what the universities have done over the last three to five years to eliminate shortages in their engineering and scientific faculty, they have used the same approach. Third, schools must offer clear opportunities for professional and public recognition. Fourth, the esteem for teaching as a profession must be raised.

The area of recognition and prestige is one the Federal government can do something about—at least on a national level—and one that this administration has certainly emphasized. I am pleased to tell you that we have just announced the recipients of the 1985 Presidential Awards for Excellence in Science and Mathematics Teaching. We have invited 104 secondary school teachers from all 50 states, the District of Columbia, and Puerto Rico to come to Washington later this month and be recognized for their outstanding teaching abilities. This is the third annual round of these awards.

To be sure, the cash amounts are small—$5,000 to the teacher's school to supplement their programs, and additional donations from the private sector. But we believe this awards program is important because it focuses the nation's attention on some of our best math and science teachers. That in itself should encourage other high quality people to become and remain teachers. I would like to thank all of you in this room and your colleagues that helped in administering this particular program. We appreciate it very much.

Raising salaries, improving working conditions, and providing more recognition can help schools retain some of the people who would otherwise leave teaching for another career. Schools can also do more to tap knowledgeable people in industry and in universities, and they are doing this more and more. Engineering schools, for example, are dealing with their tremendous faculty shortages in part by hiring part-time instructors who hold jobs in industry. If they can do that, why can't we do that in elementary and secondary schools? Another source is the pool of retired scientists and engineers that exists in some parts of the country. Experimental programs, I believe, are operating to place them in the classroom in Florida and here in D.C. and I suspect that properly approached and properly prepared, retired scientists and engineers could be a very viable kind of a resource.

In closing, I would like to say once again that NSF recognizes the importance of precollege science and math teachers. We have established what I hope will turn out to be useful, though small, programs that are appropriate to current conceptions of the federal and NSF role in this area. We will continue to depend on leverage and partnerships to make them even more effective. I hope that local governments and funding bodies will act on issues of monetary and intellectual rewards and on improving the ambience for effective teaching. Finally, I believe that forums like this one will eventually succeed in finding better ways to attract, motivate, and reward teachers in the very critical fields of mathematics, science, and technology.

M. Carl Holman, *President, National Urban Coalition*

– on the need for generalized science literacy

I would like to focus on three questions: (1) what is the current atmosphere in which science teaching occurs, (2) why must this atmosphere be changed; and (3) what are some ways of going about it? I approach these questions from a narrow perspective. My biases have to do with certain experiences that I have had in the years of growing up in this country. If someone could back away and take a photograph of what I see as I look out over the audience and ask the question, "In what country was this taken?", it would be very difficult for them to say, "This picture was taken in a multi-racial, multi-ethnic country, 51% of whose members are women." I'm glad to see that there are a lot more women in this audience than I have seen taking certain kinds of courses in the sciences.

About five years ago, I raised with the board of the National Urban Coalition and with some of my colleagues my reaction to some census data as we move toward the 21st century. I was looking at the disturbing projected birth rates for low-income hispanics and blacks. U. S. birth rates have been declining for most middle-class and affluent people whether they are black, hispanic, or white. Also the youth cadre for the 21st century is going to be disproportionately coming from low-income blacks and hispanics. I suggest that this country does not behave at all as though it believes these data to be true. And when I say that I'm including all of us in this room and some very powerful people over on 16th Street and some people up on Capitol Hill and a great number of people around the country.

The second thing: We had a conference right here in this room —(I keep coming back to holding these national education conferences, I don't seem to learn)—and John Gardner, no less, said to me at one point, "Carl, we're doing so well on economic development issues and housing issues and all that. Maybe you ought to just let that education business go for awhile until they get themselves together." I said, "John, you were an educator, I was one. The whole notion that education of, by, and in, itself is going to get itself together is hardly worthy of a man of your eminence and intellect."

There has been a decline in the effectiveness of urban schools as we know them. What amazes me is that when I talk to scientists around the country who are coordinators of science in the United States, they will agree to speak to me only if they are not quoted and their names are not used. One person said to me, for example, "I think you need to know that for almost 200 schools we have two people who are doing science coordination. When I found a biology Ph.D. who really wanted to teach even though she knew how bad the salaries were and the rest of that, I rejoiced and I sent her name and credentials to the personnel department. They sent them back to me saying, 'Sorry, she does not have the required number of hours in education.'"

When I was going to school as a young black in Missouri, I was told, "Whatever you do, you must take education, because you may have to teach." Notice that: you may have to teach, so you better take some courses in education, which I did. So, I wind up trying to get out there in three years and at the same time carry two majors and two minors, because I was determined that ed[illegible] not be my only minor. As I look back on it, I met a couple of [illegible]easant people, but I've had a very difficult time trying to figure out how all those hours I took in education really made me a better teacher.

What I think is a critical problem is that if we believe in the importance of surviving as a country, we are going to have to take a very hard look at who it is we want to have teaching science. We're going to have to face the reality that now that women and blacks and hispanics and whites who are interested in science can get other kinds of jobs, few of them are willing to put up with the requirements that most states exact. The shifting of our economy from an industrial base to a technological and service base comes at a time when there is a critical gap between minority and female students and their peers in scientific and technological literacy. It has serious economic and social consequences for the next generation.

When I speak of who has to get bilingual, I'm including who has to get bilingual in terms of the people I deal with every day as well as the people who I worked with as a young college teacher. I suggested to my colleagues, college teachers in English and math and science, that it might be a good thing for us to sit down with the high school teachers in those fields since it was evident that we were looking for and talking about and aiming at quite different things from them. I was shocked that the college professors did not want to waste their time with those benighted people, because if those people are any good, why are they sending us the kind of students we get to work with in college.

I find the same kind of thing very often. The answer lies in how we make science teaching a profession. As a person who heads a labor union, I think the question of trying to deal with educators and education as one more trade or industrial union is probably not precisely the way to go. The people who have the most to give in terms of getting us ready for this scientific technological future are, to large degree, inaccessible to the people who most need it.

Now the gloomy dean of Wall Street, Mr. Kaufman, said last year, "The people keep thinking that our big problem in this country in terms of its future is finance capital and what happens to it and how we acquire it and how we use it. That's not so." He says that the basic problem we face is a problem of human capital. At this particular point we are in a sad state of affairs because you're not totally to blame.

Mr. Reagan has done a number of things that I don't totally agree with. One thing he has done proves to me the potency of the presidency. If the President says, "This is a problem," it is interesting to see how governors, how state legislators, how those people who didn't even want to come to our conferences when we were talking about this to reporters begin to pay attention to it. Now I don't think we are necessarily going to be saved by school prayer or tuition credits, but I do believe that we had better seize the current, sometimes passing, interest in education and what happens there to see what we can make of it and see how we can utilize it.

Some say that computers have become universal but I can take you to schools where there are no computers except in the business office. I believe it is the University of Pittsburgh that is requiring every student to have a computer. It is Harvard, I think, and one other school in Boston that says, "You must have one and if necessary, we'll give you a student loan." In 1981 only 5.8% of the degrees in physical science, only 3% of the masters degrees in science, a dismal 0.9% of the degrees in the physical sciences, and 1.5% of the life science doctorates went to blacks or hispanics. The figures are somewhat better for women but not markedly so. That is not basically an indictment of scientists. That is not basically an indictment of the National Science Foundation, which I would like to see with a large budget although it is satisfied with the budget it has. That's not the fault even of all of the parents that I have been trying to talk to and deal with, but we have to face some realities. Black and hispanic leaders and business leaders and politicians and the people in the sciences are going to have to face up to the reality that unless they change the atmosphere in which all that we are talking about takes place now, the situation three, four, five years down the road will be worse.

I'll begin with one of the cases on which we are trying to focus our attention. I think there is something illogical just because a number of reports about what is wrong with the schools focus on the high schools, and why not? Businesses get interested in students at the high school level because the students are about to come into the work force. Colleges get interested because that's about the time that they will be coming into school.

But what have we seen? We have known for a long time that it is at the kindergarten and the preschool level that black and hispanic kids are closest in achievement and in learning to their white peers and that gap widens and widens until in some schools 50% of the kids drop out; most of them have not mastered even the fundamentals of thinking scientifically. I used to trust you scientists a great deal because all that stuff I learned and was told would never ever change again did change. But the important thing is that when these kids and these parents are most vulnerable because they are enjoying what they're doing and you're sort of painlessly injecting them with an introduction to science and the curiosity that is in science.

What you actually find is that you can at least get them to master the principles. You can get them to understand the processes that are so basic in terms of science. By the time my students got to college they were saying, "I don't want to take English, don't want to take math, don't want to take science, because they are hard subjects." We have arranged in some cases to help them do that by giving them electives in the theory and practice of volleyball, for example.

One person has said, "We have got to get rid of all the teachers we have and start all over again." Well, unfortunately, even if there were no tenure, you could not do that. Hard as it is to retrain some of the teachers that we now have, they are going to have to be retrained. Believe it or not, parents and families still have a great deal of influence on children.

So I'm not surprised that Jim Comer and the others at the Yale Child Studies Center have been able to bring low-income parents into the schools not just to sell cookies but to get them involved in trying to understand this educational enterprise. I can show you a school that has the lowest-income neighborhood in New Haven, and they have the third highest scores in reading, math, and science. This did not happen by magic, it's very hard work, and there have been a number of battles over the five years it took to make this happen. But the gain is worth accounting, and the fight is worth having.

People don't like to talk about money and teachers. I learned that a long time ago. But it's still very true. Maybe we shouldn't have an elite? One of the problems facing education is that almost every other American field of endeavor is vertically arranged so that you go up the better you get. Sometimes you get the Peter Principle working but nonetheless people still think that CEO's are worth those million dollar salaries and bonuses they get. But one of the things which is very strange about public school teaching is that it tends to be horizontal. There can be only one superintendent, and a few assistant superintendents, so what do teachers strive for? They strive to get tenure and the right to choose where they will teach. Then when they get tenure, they get out of those schools in the inner cities. They move to the periphery.

We are going to have to do something about the base pay of all teachers before we can attract some of the people who are watching. If it is indeed in the national interest of this country to have more scientists, more technologists, and more technicians, somebody is going to have to pay for that. I hope the English teachers get their chance next time round, but the truth is that those governors who now favor loans to people who go into those fields are on the right track. We are an incentive-minded people. If you don't believe so, tell these people who are running all of these big companies—"the bonuses are gone, the salaries are gone, but look how much great and good you are going to be doing for the country"—and see what happens. I think we have got to understand what the head of American Can said the other day, "It's well and good to have these special programs such as Adopt-a-School—some of these programs are very useful—but you don't make many systemic changes that way."

If blacks and hispanics are serious about the future of their children they are going to have to be bilingual enough to take some bitter medicine and start learning how they can get their kids to embrace the tough subjects—math, science, technology. One of the things happening is that over and over again people whose kids are not in those schools will not vote for school bonds, so it's a political problem. The political atmosphere requires that we all work at saying, "If this educational enterprise is important, if science, math, and technology are important, then we've got to testify before these grubby people in state legislatures and school boards."

My friends who have worked on bussing and that sort of thing have to understand a very bitter reality which is that most of the black kids in this country for the foreseeable future will not be in alternative schools, will not be in parochial schools, will not be in private schools, but will be locked into public schools. Unless the scientific community, the political leadership, and black and hispanic parents and organizations can begin to change the political environment in which we make science teaching possible, the figures we look at in 1995 will be worse than they are now. I hope that you will remember that there are a number of superintendents, teachers, and parents who now are beginning to get hungry for what you can provide for them. It calls for a little bilinguality on your part and a lot of bilinguality on their part. Thank you.

Paul E. Peterson, *Director, Governmental Studies, The Brookings Institution*

— on economic and policy trends and proposals

I believe that the paper that I've prepared has been distributed to you and I'm sure that you spent last night carefully perusing it. But let me just go over some of the major points that I made in it. I started off with the argument that Americans, today, learn less in math and science. They learn less than do their counterparts in other industrialized countries. They learn less than they used to. And they seem to be less exposed to educational experiences in this area than they are in the reading and the language arts.

The reasons for this lack of experience are probably deeply rooted in American culture and politics and, because of this, are not easily changed. America is an egalitarian society where everyone stands on equal footing and where verbal acuity and personal expressiveness arc essential for making one's way in the world. And the American economy runs by the principles of the marketplace, an arena which demands high level bargaining and negotiating skills. In such a society, the scientific method and the order that mathematics imposes takes second place.

Unlike the ceaseless spontaneity of the United States, such precision better suits the Japanese and European countries. I believe that in some sense the problems that we continually discuss are intractable. They are so deeply rooted that they're not going to be changed by any activities of our educational system.

However, there are more proximate difficulties that do seem susceptible to policy analysis and revision. In my view, when you start looking at the specific problem of teacher education in mathematics and science, as this conference is, there's one simple answer that stands out in bold relief. Pay these teachers more. However, we have not chosen that course of action and that's what the rest of my paper is about. Why is it that we don't increase teachers' salaries but instead look around for alternatives that are probably not going to solve the problem unless we address that fundamental question?

I develop this argument by making four major points. First, I focus on the overall trends in teacher quality in analyzing the performance of students, and second, trends in teacher quality, supply and demand, third, the political difficulties that are associated with paying teachers more, and fourth, I analyze a few proposals that have been advocated to address the problem of math and science education.

I don't want to give you a lot of facts on how poorly American students are doing in math and science. You know this as well as I do. However, to give you an idea of the significance of this problem, I'll just mention the most important study, done in 1964. It was a survey of 8th grade students in 12 countries. The United States ranked 11 out of 12. And the U.S. average has dropped in the 20 years since then. We're no longer at the bottom of the list, but that's because they've included more countries in the most recent survey and a third of the countries are developing nations such as Hong Kong, Nigeria, and Swaziland. Therefore, if you compare the United States with other industrialized countries which have comparable resources for educating their population, the United States remains surprisingly low.

This leads me to the question of teacher quality. Of course, there's always been a problem of attracting math and science graduates to the teaching profession. There's nothing new about it. It's been around at least throughout the postwar period and I would guess well before that. However, it is getting worse. The data show that the problems of recruiting people in these fields into education are more severe today than they were 10 or 20 years ago. And what's more, the problems of recruiting quality teachers in general have increased. In 1973, high school seniors intending to major in education in college scored 32 points below the average on the math portion of the SAT. So, people going into education usually score below the average of all kids going on to college. But that has widened from 1973 to 1982 and so now they're scoring 48 points behind the average on the math portion of the SAT.

If you look at who's teaching today, there's only one measure available and it's not a very good one. Yet, it shows a decline in the quality of all the people teaching in education. Moreover, I would suggest that the problems in math and science are much greater than in education as a whole.

The reason I suggest this is because teacher compensation has decreased over the last decade. If there's a decline in teacher quality, it's probably because we're paying teachers less. As a result of this, the bright people are leaving and going into other jobs or the bright people aren't going into education in the first place. If you look at teacher salaries over the last 10 years, they have fallen. They have fallen by 12% if you look at 1970–1982. If you go from 1972–1982 it's by 22%. It's somewhere in that range.

Admittedly, hourly earnings on the part of all Americans have also fallen in the 1970s and early 1980s. We're not as prosperous a country as we used to be. Our household income is higher than it used to be but that's because we have a higher number of people from each household in the workforce. But overall hourly earnings are less than they were 25 years ago. Yet, teacher salaries fell even more rapidly than elsewhere and as such teacher salaries relative to those in other occupations are worse today than they were 10–15 years ago.

This part is not surprising because in 1970 you had the baby boom going through the elementary and secondary schools, and there was a tremendous demand for teachers. Earlier, you had experienced the baby bust—the depression kids going through college and coming out entering the labor market, so there weren't as many teachers around as were needed, and so salaries went up. The price of labor went up in order to attract more people into this field.

We then experienced a reversal of this trend. The baby boom graduated from college and a new baby bust was going into the elementary schools. The demand for teachers fell while the supply of teachers was greatly increased. The amount schools had to pay teachers to attract teachers fell and the trade unions and the National Education Association were really unable to do anything about it.

Now the cycle is beginning to turn around again. We are moving into a period where we're going to experience a shortage of people graduating from college. The demand for teachers is increasing again—not like the baby boom, it's a baby boomlet this time—but there are going to be greater demands. We're now beginning to feel the demand in our schools. The result is that we're going to have to start paying teachers more.

However, in order to get back to the 1970 salary levels—just to get back to those levels—which are about 10–20% higher than those today, we're going to have to increase by one half the percentage of our gross national product that we spend on public elementary and secondary schools. We're going to have to raise the percentage from 3½% to well over 5%. We did this once before between 1948 and 1960. In 1948, less than 2% of our gross national product was spent on public elementary and secondary education. By 1965 we were spending over 4½% of our gross national product on education. We did that because of the baby boom and of a great enthusiasm for education in this country. We went from less than 2% to over 4½%—a remarkable increase in America's commitment to quality education. It slipped a bit in the 1970s and fell down to 3½% by 1980. That is due in part to the shortage of school-age children—we don't have to spend as much money if there are fewer children in school. It's also due to the fact that teachers were paid less. Now we're going to have to shift to higher salaries once again if we are going to attract more people into education and improve teacher quality.

Will we do it? I don't think so. I don't believe there's anywhere near the enthusiasm for public education that there was in the 1950s. That raises the question of math and science education all the more acutely, because it is the math and science teachers who have to give up the best wages in other occupations to stay in teaching.

When one looks at salaries at the college level, it is interesting that in the universities chemists, physicists, and mathematicians are paid more than people in the social sciences and the humanities. And the university community accepts this. If you look at the data nationwide, there's about a 20–25% salary differential between the two types of fields on the whole.

At the high school level we say we can't implement this policy. You must pay everybody the same. Well if that's our policy and there are certainly strong forces in place to keep it our policy, then it will inevitably be the case that the shortage of math and science teachers is going to continue.

The answer, some people say, is merit pay. I'm against merit pay. I think merit pay doesn't get at the root of the problem. The problem is not that the math and science teachers are better teachers than the English teachers so they should be paid more. Quite ironically, the problem is that they're probably worse teachers on average. The best qualified teachers have left and gone somewhere else. So you've got to pay more money to less-qualified teachers in order to bring the math and science up to where elementary, social studies and English teachers already are.

The other solution Congress has come up with in all of its great wisdom is to provide more training, stipends, and scholarships in math and science. The problem is you can do all the training and all the education you want but so long as there are better jobs elsewhere, the good people who get the training have every incentive to leave the field and obtain more interesting jobs in other spheres of activity.

I'm basically arguing—and there's more to it than what I've been able to summarize here—is that one answer—not the only answer to be sure—but one answer to the problem of teacher education in math and science is to pay these teachers more. If it is not feasible to pay all teachers more, at least those critical areas such as math and science should be considered where the shortages are so severe. You've got to pay these teachers more. If you're unwilling to do that, the principle of equal pay is the principle by which we're going to live and die with in education. People will come up with alternative schemes and plans and ideas that are going to make a lot of politicians popular, but they really are not going to address the fundamental question that plagues teacher education in math and science today.

Gordon Ambach, *Commissioner of Education for the State of New York*

– on empowering science teachers

I didn't plan to say anything about tax reform, but if I could link Paul Peterson's comments about the commitment of this nation to education, I would make the commitment with tax reform. If you don't keep your eye on what's happening by way of tax reform at the federal level in this country, especially with respect to the deductibility of state and local taxes from federal income tax, with the same eye on the issue of what we're going to be spending for education, then frankly we're kidding ourselves. That is the most critical issue in this town today by way of what's going to happen in terms of educational expenditure for the years to come. But that's not the topic this morning.

Yesterday at about this time, I was at the Buffalo Zoo. Now there are folks in New York who think maybe that's an appropriate place for the Commissioner of Education of New York State to be, but some might ask why I was at the Buffalo Zoo. The fact of the matter is I was visiting a science magnet school that serves seventh and eighth grade children. It is located right in the middle of the zoo. It's an extraordinary school, and it was developed to link Buffalo's educational and cultural resources. It was recognized as one of the top 10 middle schools in New York state. Secretary of Education William Bennett and President Reagan just a couple of weeks ago recognized it as one of the top schools.

I raise this point because we're spending a great deal of time this fall on the issue of strengthening teaching. Not just in science or mathematics, but strengthening teaching broadly. When one visits a school like that, one asks the teachers who are there, "What are the key ingredients that determine the effectiveness or the quality of that particular school?" They are the same teachers who were involved in the other schools, but there they are with a very high motivation. There they are with a particular challenge to themselves, developing their own capacity to teach and learning new ways and learning new aspects of science or the other fields for them to teach. The teachers say that the principal ingredients are the time to plan and work together on curriculum development and on their own professional development, and the opportunity to have direct contact with the scientists and the others who work in the zoo as they plan their activities together.

And ladies and gentlemen, the matter of breaking through the problem of the isolation of the teacher in our elementary and secondary schools, no matter what the field may be, and bringing all of our persons in the elementary and secondary schools into a colleagueship with those who happen to be in their fields is a very, very critical issue in terms of the motivation and quality of education for the future in this country. I agree completely with what Paul Peterson has said about the salary issue and the matter of overall commitment that we must be making to education in this country, and the increase that's necessary. I don't think I need to keep harping on that. I'd like to speak to some other issues this morning which I believe are also important. The topic I was asked to address is standards and quality, and particularly to make some comments about the issue of testing— testing for ensuring standards and quality.

I come to this issue from the perspective of one responsible for the entire educational system in New York, from the very earliest years through the most advanced studies. All of the colleges and universities, independent and public, all of the schools, public and private, and incidentally all of the cultural institutions, professional licensing, vocational rehabilitation, and so on. It's a perspective that tries to see a comprehensive concern about education and quality. It attempts to knit together what has to happen in one sector with what happens in another. We're very proud of certain of the results that have occurred within the state over time and in competitions nationally. It doesn't matter whether you look at the Advanced Placement Exams or the Westinghouse Science Talent Search or achievement testing with the SAT program. We're very proud when we look at those kinds of results—for some of our students.

However, our concern must be for the entire system and for the teaching of mathematics and science to the entire population, and that must be recognized as a very massive task. If we want to work in elementary school science, in our state alone we're talking about reaching 80,000 teachers who teach elementary science. They are the elementary school teachers. If we want to work with those who are specialists in the sciences, we're still dealing with upgrading thousands or tens of thousands. I point that out because it's absolutely essential to understand the massiveness of what it means to be in retraining or be in staff development or to work through new curricular developments.

Setting standards or ensuring quality for those who are teaching in the sciences starts with setting the standards and the quality of what we expect the students to be able to know and to do. That's why in our state, within the framework of reforms that we started well before all the national reports were under way, we begin by establishing the overall objectives. What are the requirements of courses for diplomas, and what are the expectations by way of studying science at the elementary or the middle-school level? You translate those into general goals and objectives, and frankly you translate those into a system in which you can monitor the progress in the science program.

We have quite an elaborate structure for examination in the sciences in New York state. Our Regents program, which tests individuals course by course, is 100 years old. And incidentally, it was first put in place to test whether the teachers were testing, not whether the students were learning. We're accustomed to having that kind of a pattern, and I think that there is a general acceptance now across the country of those kinds of tests for students.

But our concern here is mainly with teachers. The issue of testing with the teachers, I think, has to be looked at in this way. There is a move across the country by way of using the National Teacher Examination (NTE) or using other kinds of tests for the entry of all teachers. In fact, in 1980 we adopted that use within our state, using the core battery check on certain capacities or skills for all elementary and secondary teachers coming in. We have been exploring the use of specialty examinations in the sciences, and we have had validity studies done to determine whether we could use the NTE. We find this limitation: The NTEs tend to combine biology and general science, or they tend to combine physics, chemistry, and general science. Frankly that's not the appropriate use as far as we're concerned because we certify in the specialties of physics, chemistry, biology, and earth science. So we don't think we can use those tests. We have looked at whether you could ever use the Graduate Record Examinations just as a check on general science knowledge. We found them wanting for this particular purpose as well.

Why did we look at that? Because of the fact that even though it may sound good for a state to move to a specialty testing program, we know from extensive experience because we license all professionals within the state (architecture, medicine, dentistry, social work) how complex it is to be able to measure professionals, how costly it is, how difficult it is to get consistency over the years, how much it takes year by year to keep producing the examinations, and how much of a problem there is with respect to security in the administration of these examinations, where one's career or one's profession is on the line and it is absolutely essential to have security. We've tried therefore to see whether there is any system that we could use for this aspect, but we have found them to this point wanting. We will not give up on that because we believe it is important that we do have in place a certain element of testing.

Let me hasten to add that we have no illusions that by testing we're determining whether someone is going to be a good teacher. We are simply testing whether they have a certain skill level or whether they have a certain capacity in the content of the subject that they are about to teach. We cannot tell whether someone is a good teacher until he or she starts to teach and we carefully evaluate what they are doing. In summary, we have a strong tradition, and we will continue to use the tests for what we think they can usefully produce for us. They are very important checks on whether persons are literate, whether they can compute, or whether they know something about a particular subject that they are expected to teach. But you can't push them beyond that.

I would make this one point that comes to us from enterprise, which now has a deep concern for quality of products. And the point is this: You cannot inspect quality into a product. Many people have the idea that you can begin to test and that all of a s[illegible]en the product is going to be better in quality. It won't be better unless you do other things with it.

What we must do is to put our heads together and get the consensus that's necessary about the changes that are needed. These changes concern salaries but also other very key steps, especially recruitment and the provision of fellowships and scholarships. Don't underemphasize that. The good news, and it may not be across the country but it's coming from the state of New York, is that the number of applicants in science education is in fact increasing, especially from 1980 to 1985. Yes, there was a big decrease from 1968 to about 1980, but over the past few years, the percentage of increase in science education for us has been at about 25–30%. Now, we're nowhere near where we were earlier, but the trend is up, and the scores on the various tests, whatever they're useful for, are in fact going up, and the level of concern about this training at the graduate level is going up, and the number of people who have been in occupations other than education who are interested in coming into teaching is also going up. This is encouraging news.

I'd like to finish with just a couple of points that have to do with those in current practice. You can institute entry-level exams to screen applicants, but you must remember that 92% to 98% of those who are in teaching are already there. Just as our businesses and industry have promoted quality by focusing on who is in the work force and how to motivate them and prepare them and train them to do a better job, we must do the same thing. That means a substantial commitment to inservice training and summer programs that supplement salary and provide training. It means substantial commitments to giving time to those who are in teaching to learn anew what they should be teaching. We're talking here not only about those who are in secondary schools where there is a specialty in science. We must keep in mind in my state those 80,000 elementary school teachers who are expected to be providing at least a foundation of concern in the sciences, of capturing that tremendous enthusiasm and inquiry that youngsters have about phenomena around them that either is going to be stimulated or snuffed at that point. When we think about those teachers as well, it is a very substantial task, not of starting anew, but helping when we can with the new advances. That is where we build in the quality. We can test it later, but if we don't build it in, it won't work.

I conclude with one comment that goes back to the science magnet school in Buffalo, and that is the issue of colleagueship. The point was made about the distinction between what tends to happen in our nation for the collegiate faculty versus what happens with the elementary and secondary school faculty. If you haven't heard of it, you will be hearing more about it across this land—the term "empowerment" for those who are teaching, and the term "control of curriculum for peers," for all of those aspects that we've taken for granted in the collegiate world and yet that are not really in many respects a core aspect of what happens in the elementary and secondary world.

Together with the issue of remuneration or compensation, the issue is very much one of what the condition for teaching is and whether or not the teachers have significant control over what they're doing in the schools. That being the case, it is absolutely critical to be dealing with that empowerment issue and to be dealing with the relationships that we are particularly responsible for, that is, being certain that those who teach science in the elementary and secondary schools are considered genuine colleagues of the scientific community, are considered to be closely related to those in the societies and those in the collegiate institutions. Unless we can develop that kind of vertical relationship, the whole question of status and motivation will not be properly dealt with.

Amado J. Sandoval and Doris Sandoval, *Chemistry Teachers, Maryland High Schools*

– a teacher's-eye view of the situation

We are witnessing a tremendous increase in the apparent interest in education and education problems on the part of politicians and public figures. I don't know if as educators, and more specifically, as science educators, we should derive any joy or pride out of discovering that our problems are as important as the national deficit or the latest bombing in the Middle East. I guess one benefit of making the cover of *Time* magazine under the big headline "Help! Teacher Can't Teach" is that we may get some needed public attention.

We have also been presented with innumerable books, articles, and commission reports on the state of our education. Of course, we are all familiar with some of the statements that have been highlighted by the news media: "A tide of mediocrity has devastated public education" or that by allowing the present state of affairs to develop "we have, in effect, been committing an act of unthinking, unilateral educational disarmament" or "that if an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act of war."

These are very strong words. We may disagree on the extent of the problem. As scientists, trained to express our thoughts with very precise language, free of any kind of exaggeration, we even feel a bit uncomfortable. Some may view the choice of the words as a rhetorical hype designed to arouse public opinion. We all agree, however, that we are facing a crisis. Crises, as mentioned, may make for uncomfortable experiences. I like Dr. Pimentel's position: Let's take advantage of the crisis and count our blessings.

As science teachers we are particularly touched by many of these public outcries. Our high school graduates may not be able to read work application forms, let alone Shakespeare or Hemingway. They may not be able to tell which ocean borders California. They may think, if they do at all, that Dante Alighieri was a Mafia don or Santayana was a Latin American musician whose brother plays shortstop for the New York Mets. I suspect that as much as they have a reading problem or they lack an adequate knowledge of geography or literature, the public will decry primarily our slippage in math and science and technology. The Japanese are catching and surpassing us in microchip technology, German engineering produces higher quality, the Soviet Union graduates more scientists and engineers.

We had better do our part in improving the quality of our science education. Will Rogers was once asked what could be done to improve the quality of the penal system in the United States. His response was: "Improve the quality of the inmates!" If we want to improve the quality of science teaching, let's improve the quality of our science teachers.

Yesterday and today you have heard a number of very valuable ideas and suggestions concerning science education. To that end I would like to offer some practical and concrete suggestions on the tactical level. I speak to you as a high school science teacher and what I will share with you are ideas that have been shaped by my classroom experience and my wife's classroom experience and by our interactions with students and colleagues.

I would like to suggest a few "do's and don'ts" towards improving the quality of science teaching in our schools. Let me begin with a big "don't."

Don't be unrealistic and unfair in placing so much of the blame for our science education problems on our science teachers. We share the blame, I am not denying that. But let us not forget that many of the problems we face today, not just in science education, but education in general, are simply a continuation and a reflection of the problems of our modern society. And this is not a copout. Let's be realistic.

It is very easy to look at our deficiencies and to turn around and look at the Japanese or German or Russian children and sadly shake our heads and say "They do it, why can't we?" What is wrong with our educational system? The average Japanese ninth grader knows quadratic equations. We feel great if our juniors and seniors can solve a simple first-degree equation. Russian and German high school youngsters graduate having had seven, eight, ten years of math and science. Some of our more enlightened states require two years of math and science in order to get a diploma. Others require less than that! Assessment tests of one type or another consistently place our youngsters near the bottom of the industrialized nations.

How do they do it? Their society allows them to do many things our does not. And our society allows our children to do many things theirs does not. I would love to see the expression on my Japanese counterpart's face if he were summoned to the Principal's office as a result of a parental complaint and were told to cut down the amount of homework assigned; or if he received a note from a parent asking for a postponement of a child's test because he or she had not been able to study over the weekend because the family had gone to the beach. How much TV do Russian children watch? How many German children are allowed to work four or five hours a day to earn money to pay for designer clothes, or stereo sets, or their own "set of wheels"? How many of these youngsters are allowed to get out of class to "prepare for a pep rally" or to decorate the gym for the night's student government dance? I don't have to go on.

We will work on improving what we are doing and will try to do even more of it, but some of the values and customs of our society must be changed dramatically before we can achieve those lofty goals.

Now, after that *caveat*, a few practical "do's." First, continue to strive to make teaching, and science teaching in particular, more attractive to young men and women. Realistically we will never be able to compete with private industry in terms of dollars and cents. It would be absurd to expect that. Besides, many of those youngsters who would not even think of becoming a teacher because of the low salary would not make decent teachers.

It takes a certain amount of idealism to be a good teacher. We don't like to admit that for fear of having people (especially boards of education) take advantage of us. They do anyway. Don't get me wrong. We want to live as comfortably and make as much money as possible. But the immense majority of science teachers are in this profession because we made a choice, a conscious choice, knowing full well that because of our training and background we could, and in many cases still can, go into other fields and make more money.

If we improve the salary and image of the teaching profession we may be able to attract some of those youngsters who now go for higher paying jobs, but who are idealistic enough to take that initial cut. Let's work towards changing the esteem or lack thereof with which our society views teachers, so that we don't hear more comments like the one offered by a student during one of Secretary of Education William J. Bennett's appearances last month at a local high school when asked how many of her peers would want to become teachers: "I guess there may be a good number, but most" of our "students are interested in being something above that, like a doctor or a lawyer."

Our effort at recruitment would require some sort of public relations campaign, but more importantly this will demand a change in the way in which we are treated. Our boards of education can stand some improvement on this. The public reads the newspapers, they see and hear how we are treated and they draw conclusions. If our own employers feel the way they seem to feel about teaching and teachers, what do we expect from other people?

The same board of education that at the beginning of the school year talks very sweetly and tells us how much it appreciates what we are doing takes a different attitude three or four months later when the time comes to negotiate a new contract. What we were told was going to be a very professional relationship had become all of a sudden a management-labor struggle! A potential science teacher may read about this, in some cases will even see television coverage of the picket lines of striking teachers, and decide that he or she does not care for this kind of hassle.

Next, let us change the training process and certification requirements for science teachers. Ideally the beginning teacher should have a solid training in the liberal arts, a thorough knowledge of his/her science field, and a working mastery of the theory and practice of education. Realistically we know we cannot expect this from every beginner. We hope that at least the teacher candidate will be an educated individual capable of helping others to acquire knowledge.

How is this to interpreted with regard to a science teacher candidate? I would like to see a much greater number of beginning teachers with a major in a science field, rather than a degree in education with some courses in science.

I would like to suggest two measures that might help in this regard. First, school systems could offer a differential starting salary scale. It has been pointed out that, politically, it is unrealistic to expect a differential pay scale for science teachers already in the system, given the reality of collective bargaining. But given the reality of the job market, teachers' unions may accept a differential salary as some sort of "signing" bonus. Beginning teachers with a major in the field they are going to teach, physics, chemistry, biology, geology, would begin with a higher salary than a person with a general degree.

Second, we must make it easier and more attractive for retired scientists to acquire teacher certification. Some areas of industry were severely hit by the recession of just a few years ago. Many of them, in order to reduce their work force without laying people off, developed early retirement incentive plans. For some reason, the pattern is more widespread in the chemical industry. Many U.S. businesses took this route in the early 1980's and then stopped their incentive plans as business picked up again, but the chemical industry has continued retirement incentives. Giants in the field, such as DuPont, Monsanto, and Dow Chemical have just implemented this type of program in 1985.

We are not talking about trained scientists giving up well paid jobs in industry to begin a teaching career. What this means is that there is a large pool of relatively young, well-trained scientists from whom many good science teachers could be developed.

I am not implying by all this that all a person needs to become a good science teacher is solid knowledge of science. Far from it. It is necessary, but not sufficient. Having the knowledge does not guarantee the ability to communicate it to others. But I would like to see some changes in the present requirements for certification: Reduce the number of education courses required for certification and increase the practical training. Any experienced teacher will tell you that there was little practical use for most of what they received in their college education courses. Although some of these courses should be kept, teaching is an art. As an art, it is best learned by practice.

Prospective teachers could be required to complete their undergraduate training in the science field and to take a minimum of education courses, one of which could still be some form of practice teaching. The school system could then hire them on a provisional contract. For one or two years the new teacher would teach almost a full load under the close supervision of an experienced master teacher.

By this I do not mean some sort of "buddy system." I mean a full-fledged master-apprentice relationship program. Both the master and beginning teachers would teach a lightened load, maybe one period a day less than usual, for the same full-time salary, that would allow them "school time" to fully interact, time to discuss and evaluate teaching plans and techniques, time to review past performances.

Some school systems at present encourage a "buddy system" where a beginner teacher meets with an experienced teacher for advice and help. But they do it on their own time—during their planning periods or after school. To be truly effective, official time should be allotted.

At the end of the "training" period and on the basis of the recommendations of the school principal, the science supervisor, and the master teacher, the candidate would be granted a regular contract.

Selection of the master teachers would not be as difficult as it may seem at first. As in any human endeavor, some of the choices will not be as good as others. Some apprentices may end up working under master teachers who may not be as good as others. But any experienced principal and/or science supervisor will have little difficulty in selecting master teachers who will do a better than adequate job.

Now we have the science teacher properly trained, certified, and hired. What do we do to help him develop into an excellent teacher? Here is my last "do." Make it easier for that teacher to continue his/her education. Presently most school systems reward continuation of education by offering salary increases. Some are even enlightened enough to offer at least partial reimbursement for the expenses involved. That is very good. However, there are some hidden aspects, especially for science teachers.

First, when a school system grants a salary increase to a teacher for having completed, say, 30 credit hours beyond the bachelor's degree or for having received a master's degree, no requirement is made of the type of credit hours or the type of master's degree. Any subject matter will do. Furthermore, some of the larger school systems attempt to facilitate this process and allow credits earned under so-called "in-service" conditions. The school system hires an instructor (occasionally another teacher within the system) to conduct some form of instruction, usually for a few hours after school, for a few weeks. At the end of these in-service sessions, usually upon completion of a report or a paper, "graduate" credits may be granted and applied towards the salary increase.

In-service training can be very practical and valuable, especially for some very concrete and simple skills such as improved use of audio-visual facilities or training in computer software, but let us not anoint this low-level subject matter with the aura of graduate credit.

In any case, science teachers who are willing to further their education will require a higher dose of truly solid courses. However, at this juncture we encounter a severe obstacle. Many graduate science courses, because of laboratory and faculty requirements, are offered only during standard "work" hours. Those are also the hours when our teachers are busy teaching. Very few courses are offered either in the evenings or on Saturdays. The immediate consequence of this is that a rather small percentage of science teachers have graduate degrees in science. Many are forced, because of the circumstances, to get graduate degrees in education, in fields like human development or curriculum development, in many cases with very few graduate science credits. Would it be too much to hope that some of our institutions of higher learning will offer graduate science courses at hours when our teachers can take them?

Perhaps the burden should shift to our boards of education: Is it very unrealistic or prohibitively expensive to hope that a teacher may be granted leave on a regular basis to attend classes at a local institution? It would be an expensive investment, but one that must be seriously considered if science teachers are to stay up-to-date.

One alternative to continuing education is taking a sabbatical leave. Not many high school science teachers take sabbaticals, for a quite simple reason: they cannot afford it. I would love to take some time off to go back to school and recharge my batteries, to have the opportunity to learn about the latest developments in my field, but taking a 50% pay cut would slightly harm my relationship with my creditors.

Most local school systems probably will not have the financial solvency needed to foot this bill. During the 1960s and early 1970s, the National Science Foundation played a major role in improving the preparation and education of countless science teachers throughout the land. The summer and academic year institutes were essentially sabbatical leaves funded by the federal government. These afforded many teachers an opportunity that they could not have had otherwise and have not been able to have since.

If the present state of our education has reached such a level of crisis that it can be likened to "an act of unthinking, unilateral disarmament," I suggest that we start to apply remedies we apply to similar situations in our world of missiles and tanks. As taxpayers we allow our government officials to spend extra billions of dollars, in some cases rather wastefully and indiscriminately, because of some alleged gap in our arsenals. It would take but only a fraction of those billions to fund local attempts to improve the education of our science teachers. I know that the key phrase these days is to share the cost, but most local school systems cannot afford to share that cost. Public relations gimmicks will not do the job.

I said I was going to make some concrete and practical suggestions. Concrete they certainly have been. I only hope that, in spite of the financial cost attached to them, they are still considered practical. Thank you very much.

80

III. Background Papers

SCIENCE TEACHING 1985

Audrey B. Champagne and Leslie E. Hornig

American Association for the Advancement of Science

Introduction

Four major reports on the condition of education in the United States were published in 1983 (Education Commission of the States Task Force on Education for Economic Growth, 1983; National Commission on Excellence in Education, 1983; National Science Board Commission on Precollege Education in Mathematics, Science and Technology, undated; Twentieth Century Fund Task Force on Federal Elementary and Secondary Education Policy, 1983).[1] They concluded that serious deficiencies exist and recommended actions to effect improvements. Despite criticisms that the proposed remedies are precipitous, shortsighted, poorly rationalized, and generally unsupported by data (Peterson, 1983; Smith, 1984), the reports struck responsive chords in the public and stimulated legislative action on the state level. Attracting particular attention was the assertion that inadequate science achievement was threatening the nation's economy, security, and democracy. States hurried to address this deficiency.

Efforts to improve science education focused on science teaching, which has been identified, not surprisingly, as the key determinant of the quality of science education (Helgeson, Stake, Weiss, et al., 1978). However, concern has been raised about haphazard implementation. For example, some districts have attempted to improve instruction by recruiting capable young professionals while simultaneously tightening control over the curriculum and instructional methods. It doesn't take long for prospective recruits to conclude that most of the professional challenge they seek has been removed.

In other cases, remedies designed to solve one problem have exacerbated another. Based on the recommendations advanced in the reports, many states have increased their graduation requirements in math and science. These actions will undoubtedly strain the pool of math and science teachers that many already regard as insufficient.

[1]Other reports and books on the condition of education and teaching were published at about the same time (Adler, [1982]; Boyer [1983]; Goodlad [1983]; Ravitch [1983]; and Sizer [1984]). Summaries of them and other reports can be found in the report by Education Commission of the States (1983), and in Griesmer and Butler (1983).

One report estimates that if each state followed the National Commission on Excellence in Education's recommendations, the nation would need 40,600 additional science teachers (Pelavin & Reisner, 1983). How will we meet this additional need when we aren't even sure of how to deal with simple turnover in the ranks?

Clearly, rational, coordinated, and well-founded planning is needed. The purpose of the National Forum for School Science is to encourage and support such planning. This chapter provides a framework for thinking about one facet of the larger system of science education—science teaching—and outlines what is currently known about science teachers and their working environment. Unfortunately, reliable empirical data are scarce, and interpretations of such data are sometimes confusing.

Conceptual Framework

A qualified science teacher in each U.S. science classroom is essential to scientific and technological literacy. To meet this goal, we, as a nation and as local communities, must find answers to some important questions. Figure 1 describes a planning cycle comprised of questions whose consideration should contribute to more effective planning. Essential to this framework is the interweaving of quality considerations with questions of supply and demand. The rest of this chapter follows this framework in considering each question from several perspectives and in outlining relevant data. Graphs and figures that substantiate references made in the text are given in the Appendix.

Science Teacher Quality

What is a qualified science teacher? To answer this question, we must ask and answer another question: What do we expect our youth to learn in and from their science classes? Hurd (1984) makes the case that useful reform of science education must be guided by our educational purposes. If we can identify our expectations and values, we can determine the kind of teacher who can meet them.

Two kinds of expectations are generally voiced: those that reflect society's aspirations for individual opportunity and active participation as citizens, and those that relate to national needs in the areas of security and the economy. Realization of the first expectation results in active, responsible citizens who can weigh evidence, develop arguments, make informed judgments, and take actions that are consistent with these decisions (Hurd, 1984). Realization of the second expectation results in people who have the skills to contribute to growing sectors of the economy which in turn contributes to national security. There is growing recognition that the cognitive skills discussed above

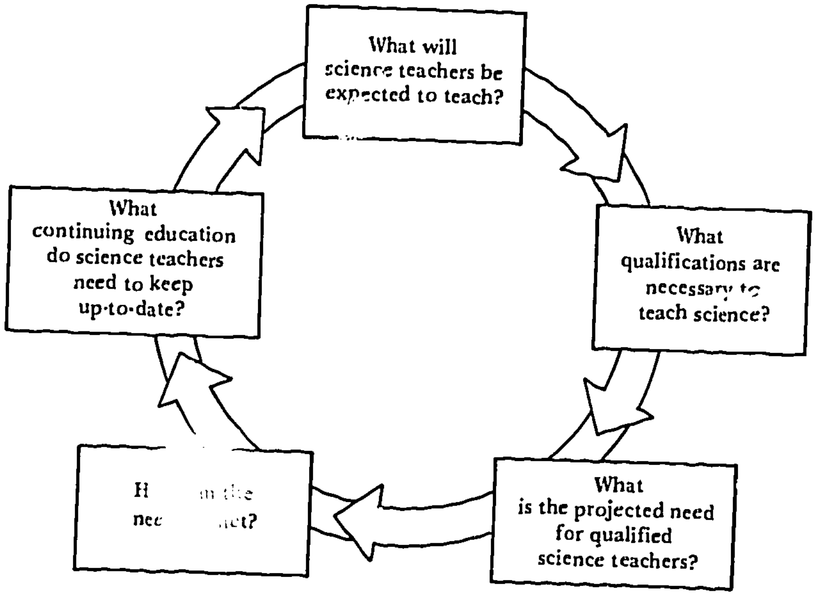


Figure 1

Planning cycle for fulfilling science teaching needs.

contribute also to individual productivity in the workplace and, by extension, to the national economy (DeForge, 1981; Eurich, 1985; Panel on Secondary School Education for the Changing Workplace of the Committee on Science, Engineering, and Public Policy, 1984).

A third expectation nestles between the first two: the production of new generations of professional scientists and engineers. This goal calls for science and mathematics education that provides the most able students, regardless of sex or race, with the skills and motivation necessary to pursue further study in science. Operationally, this means that we must provide science experiences that encourage rather than discourage.

How strongly these diverse expectations are expressed depends on historical and societal forces. Each has been emphasized recently as a rationale for improved science instruction, yet each suggests a different educational approach. We leave to others the task of divining priorities (see chapter by Harvey and Marsden in this volume, which discusses the somewhat dichotomous expectations for excellence and equity that currently coexist in our society). Here we emphasize that the practical consequences, in terms of what a teacher should know and be able to do, will vary with the instructional outcome expected. Table 1 lists some of the questions germane to these separate expectations.

Table 1

Questions germane to science teacher quality.

Expectations and objectives	*Associated questions*
Teach students to become productive citizens	What are the science knowledge and reasoning skills required in today's workplace? How will tomorrow's workplace be different? How will these differences influence the knowledge and skills required for productive citizenship? What is the function of school science in developing science skills and knowledge that will be immediately applicable in the workplace? What is the function of school science in developing life-long learning skills? What does and will a science teacher need to know and be able to do to impart this knowledge and engender these skills?
Teach students to become responsible citizens	What scientific knowledge and decision-making skills should a responsible citizen have, and how will these change as society evolves into the next century? What is the science teacher's role in sensitizing students to the ethical aspects of scientific and technological issues? What skills and knowledge are necessary for a science teacher to teach the elements of reasoned and ethical decision making?
Generate student interest in, and prepare students to enter, science as a career	What kinds of instruction stimulate student interest in science? What do science teachers need to know and be able to do to improve the participation and achievement of at-risk and high ability students?

Defining Science Teacher Quality

Even if we can agree on what the science teacher's function is, will we then know how well he or she is performing it? Clearly, a functional definition that describes teacher quality in operational terms is needed. Unfortunately, the knowledge base necessary to construct such a definition does not exist. There are many beliefs but relatively little empirical evidence that explicitly correlates performance with student science achievement.[2] Even so, definitions of teacher competence have been advanced, and typically, they are based on teacher preparation, professional practice, and product. Sometimes innate characteristics and qualities are also included.

Preparation. The preparation model bases judgments of quality on input measures: the number, type, and level of courses that the teacher has taken, or the completion of a recognized and accredited degree program. The certification standards currently used by each state use preparation measures to define quality; so do most of the standards proposed by the professional societies. These types of measures are easily determined, but they assess effectiveness only indirectly. Completion of a course does not automatically confer mastery of a subject, nor are all programs equally rigorous.

Some of the evidence that we have on teacher preparation comes from a recent study by the Southern Regional Education Board (Galambos, Cornett, & Spitler, 1985) that compares transcripts of persons majoring in arts and sciences with those of prospective teachers. Not surprisingly, differences were found in the number and level of courses that were taken. Galambos (1985) concluded in the accompanying report that education majors spend too much time on education courses and follow a general education curriculum that is too weak. Without evidence on how useful various coursework is to teachers, however, it is not clear what these comparisons mean. The report does echo concerns voiced elsewhere about the tendency of all teachers to slight the physical sciences in favor of the life sciences. Also, while acknowledging that teachers have less need for upper level courses, Galambos raises legitimate concern about the substitution of breadth for depth in a course of study. Because this study draws from a narrow population of students in southern schools, it is difficult to know how far its results can be extrapolated.

Other evidence about preparation comes from a 1982 survey of secondary school administrators concerning the number of newly hired math and science teachers who were not certified in the subject they taught (Klein, 1982; Shymansky & Aldridge, 1982). Conclusions are hard to draw from these data because they are based on a small return (38%); also there are certain puzzling inconsistencies in their presentation. It appears that in seven census regions at least 40% of newly hired teachers were not certified in their subject, and nationally the average was 50%. These data are supported by data from the

[2]There does exist a large body of research linking teacher behavior to student achievement; for an extensive review of this topic see Brophy and Good (1985). This research demonstrates that when teachers use time effectively, student achievement is high. The research is not subject-specific, however, and it does not demonstrate causal links between teacher behavior and such science-specific outcomes as science problem-solving, inquiry skills, or application of scientific information to personal decisions.

National Center for Education Statistics (NCES) (Plisko, 1983, p. 206), which indicate that 43% of new biological and physical sciences teachers are certified in a field other than the one in which they are teaching and that 11.7% lack certification of any kind.

On the other hand, Hirsch (undated) reports that in Michigan in the 1982–1983 school year, 91.2% of biology teachers possessed at least a minor in biology, and 78.1% of chemistry teachers had at least a minor in chemistry. Only 64% of the physics teachers, however, had at least a minor in physics.

Professional practice. Quality definitions based on professional practice often use the following measures: the teacher's instructional practices in terms of both the variety and preferred style; the teacher's ability to assess and meet the individual needs of the students; participation in extra-classroom activities in the school district, community, higher education institution, or professional society; and acceptance of responsibility for continuing professional education. These measures come closer to direct assessment of what a teacher must know and be able to do. Their limitation lies in the uncertainty about the causal link between instructional practices and student outcomes.

Attempts have been made to assess teacher competency through testing. As of 1985, 20 states have implemented or plan to implement competency-based teacher certification (Plisko, 1983, p. 66). With few exceptions, these states run across the southern half of the country. Teacher tests have been criticized and opposed on the grounds that they are little more than tests of basic skills, that what they measure is not relevant to actual practice, and that they are inadequate predictors of success in the classroom.

There is also some limited information from professional society membership. The current membership of the National Science Teachers Association (NSTA) is just over 25,000. Members are science educators from elementary, middle, and high schools, and from post-secondary institutions. NSTA also reports that its membership increased in 1985 by approximately 4,000 or 16% (B. G. Aldridge, personal communication, September 25, 1985).

Product. Teacher quality can also be defined in terms of student outcomes, although for the reason just noted this method is limited as well. It is probably the most controversial basis for the definition of teacher quality, but it does have historical precedent. In the 1800s the decision to retain or fire teachers was based on the public announcement of their students' achievements for the year (D. Lortie, personal communication, July 1985; Coltham [1972], cited in Dillworth, 1984). Today, teacher quality is sometimes assessed on the basis of student performance on tests of academic ability, such as the Scholastic Aptitude Test (SAT), or on standardized achievement tests. One problem with this approach is that factors other than the teacher can influence student achievement: the student's home environment, the values the student has internalized, and the resources available to the student. How does one factor out that portion of student achievement that is due to the teacher?

Innate characteristics and prior accomplishments. Another approach to defining teacher quality bases the definition on the teacher's innate qualities and on an accumulated record of academic accomplishment. Such measures include IQ and SAT scores, Advanced Placement scores, high school awards, and high school class standing. The central issue regarding the use of these particular measures is their appropriateness. Few people would disagree that, all other things being equal, an intelligent teacher is preferable to a stupid one. However, such other qualities as an ability to relate well to children or an aptitude for simultaneous problem-solving may be equally important. The problem is to define a desirable balance of qualities. Does an intelligent person who is not altogether comfortable around children make a better teacher than a less intelligent one who is adept at motivating students?

Some data have been cited—erroneously, we believe—as evidence that education majors are less intelligent than other college students. Feistritzer (1983) compiled state reports of SAT scores and found that, across the country, students who said that they intended to major in education had verbal scores that were 32 points lower than average and math scores that were 48 points lower. The gaps varied widely for each state, but in no state did the scores for education majors match or exceed the state average. These data must be accepted with two large caveats. First, the SAT is intended to predict academic success in college, not to measure intelligence (although it may measure academic accomplishment). Second, these data pertain to high school students who intend to major in education. They do not necessarily reflect the scores of actual education majors.

How Quality Standards Are Set and Enforced

Standards are set by government agencies and by professional societies; they are based on academic preparation and professional experience. Generic standards for teacher quality are specified by the general professional education societies and by the teachers' unions. Standards for science teachers are specified by scientific societies and science teachers' organizations. Enforcement plays a major role in determining the actual quality range of practicing teachers, however.

Standards for teacher certification are set and enforced by state education authorities. These generally are specified in terms of academic preparation and professional experiences (see Appendix for sample certification standards, and Roth & Mastain [1984] for a complete set of standards and procedures for each state). Because of the recent interest in teacher quality in general, many of the states are reconsidering their certification standards. Most notable are the experiments with so-called alternative certification, which grants temporary certification to applicants with good training in their subject and allows them a set period in which to accrue education credits and experience. New Jersey provides the most famous example of this innovation.

State certification standards are the chief formal identifier of quality. Studies that examine the proportion of "qualified" science teachers, for example, typically use certification to teach science as their criterion of quality (e.g., Shymansky & Aldridge, 1982). Currently, the ultimate responsibility for standards enforcement rests with the states.

Is state certification sufficient to ensure adequate quality in the science teaching force? There is some anecdotal evidence that the state's enforcement authority is not always exercised vigorously and is often circumvented by local education authorities. Similarly, when the demand for science teachers outstrips the supply, enforcement officials may look the other way as out-of-field and uncertified teachers are hired under emergency provisions (Currence, 1985b; Futrell, 1985). Sometimes, hiring laws or agreements with unions force districts to hire unwilling or unqualified teachers because of their seniority ("District court rules," 1984).

It is not clear, however, that even vigorously enforced certification standards would guarantee more than minimal quality. Critics of these standards claim that they place too much weight on education courses and not enough on subject matter, and that they include no measure of true teaching competence. Others claim that their enforcement is *too* rigid, such that it excludes otherwise well-qualified people who lack a nonessential requirement. Professional societies, such as the NSTA, have developed more comprehensive standards that rely more heavily on coursework in the subject matter, but these standards are currently voluntary. The National Council for Accreditation of Teacher Education (NCATE) uses those standards, among others, when it accredits colleges and departments of education, but NCATE accreditation is also voluntary.

This leaves us with several important questions about science teacher quality that need to be resolved. First, what are appropriate criteria for determining the quality and effectiveness of science teachers? The ongoing debates concerning the relationship of discipline knowledge and professional skills to teacher effectiveness are fueled more by the experience and personal preference of the debaters than by empirical data. Debates about the use of other criteria are no better informed by evidence. Second, can we be confident enough of our ability to measure characteristics, skills, and knowledge to use them as bases for specifying competence? It does no good to know what we want if we can't identify it reliably. Third, who should set and enforce standards? This question really has two parts: first, who is competent to set the best standards; and second, who has the political standing to enforce them.

The Demand for Science Teachers

Let us assume for the moment that we can identify a qualified science teacher. Since our goal is to get one into every science classroom, we must ask: how many will that be, and will we have enough? This question is hard to consider at the elementary level, where one is tempted to say that *every* teacher needs to be a qualified science teacher. Because little can be generalized about elementary staffing patterns, analysis of supply and demand in this area is particularly difficult. Suffice it to say that relevant data are about as scarce as elementary science specialists.

What do we know about the demand for science teachers at the secondary level? Consider Figure 2, which describes a system in which demand is determined by the number of students taking science, the courses that are offered, the way classes and schools are structured, and the amount of money that is available. Each of these factors is influenced by policy decisions that can be made at many levels, but the whole system is driven by the values and expectations that surround the role and function of science education.

Enrollment in science classes provides the first dimension—magnitude; it determines the general level of need. A primary determinant of science enrollment is the number of students enrolled in school overall. In 1981, for example, 12,879,000 students were enrolled in grades 9–12 in public school (Grant & Snyder, 1983). High school enrollment is expected to continue to decrease into the early 1990s, when it will increase slightly (Frankel & Gerald, 1982). However, not every student will take a science course every year. The actual science enrollment in any given year for grades 9–12 is likely to be closer to 60% of total enrollment (Welch, Harris, & Anderson, 1984). For grades 7–8, the percentage is much higher—90%.

What influences science enrollment? One large factor is the amount of science the state requires each student to take. Graduation requirements vary from state to state, but we do know that as a result of the recommendations voiced in *A Nation at Risk* (National Commission on Excellence in Education, 1983) state after state has proposed or im-

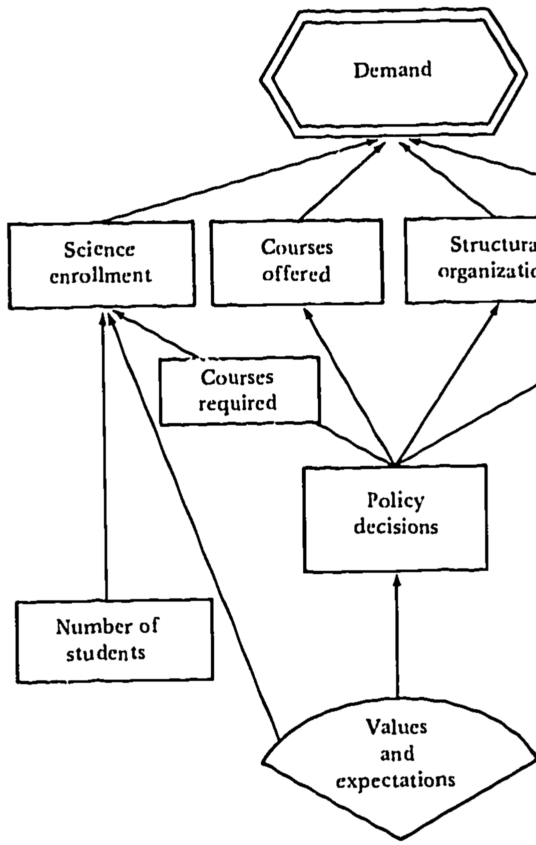


Figure 2

Factors that influence demand for science teachers.

plemented increased requirements. These often include additional math and science courses. Science enrollment would be boosted only by the percentage of students that don't already meet those requirements, but that number could be substantial. We suspect that parental values, the quality of science teaching, and university entrance requirements also play a strong role. In communities where science is perceived as valuable and the quality of science teaching is high, more students are likely to take more science regardless of state requirements than in communities where this is not true.

Enrollment determines the number of teachers needed, but it can also influence the type of teacher hired. Demographic projections indicate that, around the year 2000, one in three Americans will be nonwhite. Because Hispanics and blacks are younger and have more children than whites, so the proportion of nonwhite children will be even larger. Currently, "minorities" form the majority of students in the 25 largest city school systems and in California's elementary schools; half the states have public school populations that are more than 25% nonwhite (Hodgkinson, 1985).

At the same time, less than 10% of newly graduated teachers are nonwhite (Plisko, 1983). Although we know of no specific data, we suspect that the percentage is even lower for science teachers.[3] Further, concerns have been raised about the effect that testing will have on the racial composition of the teaching force. In Mississippi, only 24% of black education majors passed a general college achievement test administered after their sophomore year; 63% of the white students passed. Taking into account the greater enrollment of whites to begin with, 11 times more whites passed the test than blacks (Peoples, undated). The proportion of minority teachers is in danger of falling just when the minority student enrollment is rising.

Another factor that will tend to influence the type of teacher needed is the courses that are offered. We tend to speak generically of science teachers as if they were all alike; they are not, of course. Physics teachers teach physics courses, and biology teachers teach biology courses. The courses a district offers will influence the type of teachers it needs. Some courses, such as biology, are likely to have a high absolute demand because more of them are offered and elected in more districts. Others, such as physics, will have a high relative demand, that is, in terms of a shortage of applicants relative to vacant positions.

The third factor—the structural organization of the school—is the executive function that determines how the teaching force will be deployed and, therefore, exactly how many teachers will be needed. It includes such factors as teacher-pupil ratio, allowable class size, the structure of classes, and course load per teacher. In 1981, for example, approximately 7.6 million students were enrolled in science classes. Assuming that there were 19 students in each science class, an average class size for that year (Grant & Snyder, 1983), 400,000 science classes needed a teacher. Pelavin and Reisner (1983) cited unpublished NSTA data and those from unnamed other sources that established 4.5 classes as an average teaching load for science teachers. Calculations based on these figures place the national full-time equivalent for science teachers in 1981 at approximately 89,000. Not all teachers taught science full time, however; NCES (Grant & Snyder, 1983) estimates the actual number of people who taught at least one science class in 1981 at 105,000. Obviously, a shift in any of these parameters will change the

[3]Data on the demographics of science teachers are forthcoming from a study being conducted at the Research Triangle Institute under the direction of Iris Weiss.

number of teachers needed. An increase or decrease of class size by even one student could change the number of science teachers needed nationally by 5,000 or 6,000.

The final factor in the equation is finances—what the community can afford and is willing to pay. If demand is defined as the total number of science teachers needed, as it has been in this discussion, then finances influence demand indirectly, either through the courses that a district can offer or through the class size or staffing patterns a district can afford. A district with few funds may elect larger but fewer science classes, for example. If demand is defined in terms of the shortage of qualified science teachers (as is common), then the influence of finances is more direct. Low salaries, for example, that compete poorly with both industry and neighboring school districts could cause high teacher turnover. Similarly, inadequate funding for labs and other facilities could contribute to high turnover rates as teachers became dissatisfied with working conditions.

What changes are likely to affect science teacher demand? Across the country, the largest change is likely to be in the science that is required for high school graduation. After the publication of the national reports that called for improved teaching and increased student exposure to science, many of the states began considering changes in the amount of science and math students have to take. Currently, 24 states have passed legislation requiring more credits in science than were previously required (M. Bush, personal communication, September 26, 1985).

Increased student enrollment in science surely will increase the need for science teachers. Pelavin and Reisner (1983) prepared three estimates of future need based on assumptions about what the states will do. The low estimate (6,500 additional science teachers needed) assumed that only the nine states that had already raised requirements at the time of their study would raise them further. The middle estimate (13,000) assumed that only those ten states that were then considering increased requirements would implement changes. The high estimate (40,600) assumed that all states would follow the recommendations of the National Commission on Excellence in Education and require three years of science of all graduating seniors. These estimates are a bit misleading "because [they] imply a level of efficiency in the creation of new . . . classes and the assignment of new teachers that is simply not feasible" (Pelavin & Reisner, 1983, p. 23). Actual numbers could vary depending on the current availability of teachers and their subject areas.

Clearly, shifts in policy can also affect demand in other areas. Changes in the structural organization of schools could result in increased or decreased need for science teachers. If communities believe that increased teacher contact causes improved learning, smaller classes and more teachers will be needed. If, on the other hand, new uses of technology allow one teacher to serve more students with increased efficiency and quality, the call will be for fewer teachers. The creative use of teacher's aides and other paraprofessionals might accomplish the same end. Similarly, if schools alter the type of courses they offer—for example, courses that integrate the disciplines or those that consider the social and ethical dimensions of science and technology—the distribution of demand for various types of science teachers would also change.

So far, we have discussed demand as an absolute number—that is, the number of science teachers needed regardless of how many are already hired. This is an uncommon perspective; usually demand is defined in terms of the shortage of teachers, the number that will actually need to be hired. We have discussed demand from the absolute-number perspective for three reasons. First, if we define demand as shortage, we obscure the need to retrain or replace teachers who are unqualified to teach science but who are teaching it nonetheless.[4] Second, it is difficult to define a shortage unless we have some sense of what "enough" is. Third, the data needed to describe the current alleged shortage are hard to come by.

Teacher vacancies do not reflect a shortage of science teachers because of the common practice of filling a vacancy with whoever is available. NCES (cited in Pelavin & Reisner, 1983) estimated that in 1979-1980 approximately 900 teaching positions in science went unfilled. This is surely an underestimate of the total shortage of science teachers, which Pelavin and Reisner (1983) calculated at closer to 5,300. Those authors based their estimate on the number of vacancies plus the turnover rate in the science teaching force, as modified by the number of teachers expected to be hired. If their estimate is close, the current shortage in the national science teaching force is roughly 5%.

When demand is defined as shortage, teacher turnover becomes an important statistic. NCES (1982) assumes an annual teacher turnover rate of 6% for the rest of this decade. Clearly, regardless of new stresses on the system, any attrition that is not matched by enrollment decreases and new graduates will probably constitute a shortage.

How bad is the current shortage? It is extremely important to remember that this is a national average and that local situations may differ dramatically. Survey data from two groups of studies (Akin, 1984; Gerlovich & Howe, 1982) indicate that in many areas the shortage *seems* critical. Gerlovich and Howe's survey of state science supervisors revealed that in 1982 only four states reported that they had enough physics teachers and only five believed that they had enough chemistry teachers. Only one, New Mexico, had a slight surplus in

[4]A good example of this is a headline on the front page of *Education Week* (September 25, 1985) which trumpeted, "Shortages of '85 Vanish as Schools Hire Uncertified Teachers." If only all problems were so easily solved!

either field. Akin's annual survey of teacher placement officers reveals a similar pattern: two of the four disciplines suffering "considerable" shortages nationally in 1984 were physics and chemistry. The studies disagree about whether or not the shortages are getting worse: in any event, neither provides statistics to determine if the changes are significant. In general, the data from these studies should be approached with caution since they are based on perception. Too often the studies are cited as *proof* of a national crisis. They provide excellent evidence that there may be problems in some regions and in some disciplines, but further investigation is needed to reveal the exact extent of science teacher shortages.

In sum, what do we know about the demand for science teachers? We know that more than 100,000 teachers are currently teaching science across the nation. Even if the teaching environment remained unchanged—if classes remained the same size, and the pupil enrollment didn't change, and students had no reason to take more science—we would likely have at least a 5% shortage in the number of science teachers needed each year. The survey data show that chemistry and physics are experiencing the hardest time and that their shortages feel "critical." We also know that we *can* expect a major shift in the rate at which students enroll in science classes. This shift is likely to cause a need for between 13,000 and 40,600 additional science teachers. If the supply of science teachers doesn't grow, the shortage could increase dramatically.

The Supply of Science Teachers

The supply of qualified science teachers can be thought of as a subset of the pool of people who have prepared themselves to teach science and are qualified to do so. The supply does not equal the pool because some of those who are trained decide not to teach. One way to perceive the supply of science teachers is outlined in Figure 3. In this model, the pool of prospective teachers is influenced by social and economic forces, which may in turn be influenced by political decisions.

"Social forces" basically refers to the perceptions we have about teaching and how they influence the attractiveness of teaching relative to other careers. They include such notions as the status of teaching and the values that are attached to teaching.

Most of the direct evidence for the status of teaching comes from surveys of teachers and the public. Each year since 1969, Phi Delta Kappa has commissioned a Gallup poll on the public's attitudes toward the public schools. The National Education Association (NEA) has also conducted an annual Gallup poll about teaching specifically, and re-

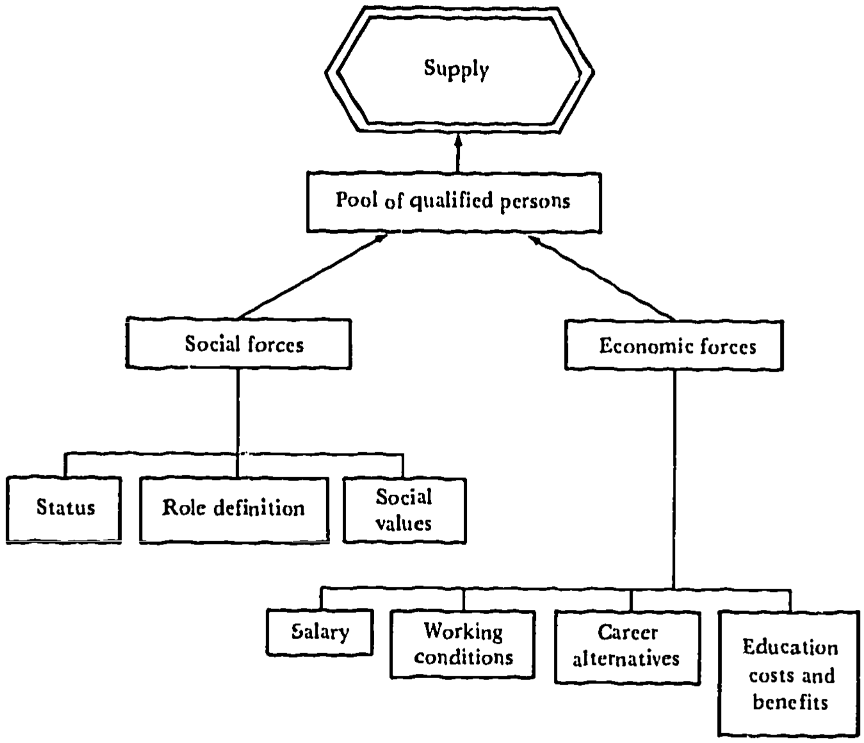


Figure 3

Factors that influence the supply of science teachers.

cently the Metropolitan Life Insurance Co. sponsored a Harris survey of teachers. None of the polls speaks specifically to the concerns of science teachers, but they all provide evidence about how teaching as profession is perceived.

The data on the status of teachers and its effects are mixed. Teaching does not rank highly when compared with other professions in terms of status: respondents to this year's NEA survey rated teachers below five other professionals and higher only than local political officeholders and realtors. Nevertheless, 67% of the respondents termed teaching "very prestigious" or "fairly prestigious." Bias, however, may exist in the cohort from which we might wish to draw teachers. When an 11th grader from Banneker Academic High School (Washington, D.C.), whose students rank among Washington's most promising youth, was asked if any of the students wanted to be teachers, she replied, "I guess there may be a good number, but most Banneker students are interested in something above that, like a doctor or lawyer" (Schwartz, 1985).

Data from teachers are equally mixed. In 1980, 52% of the teachers polled by NEA (cited in National Science Foundation [NSF] Office of Scientific & Engineering Personnel & Education, 1982) said that the status of teachers in the community had a negative effect on their morale. Sixty-six percent identified public attitudes toward school as having a negative effect, and 60% had the same opinion about the way education is treated in the media. In 1980 teachers clearly believed that the public held education in low regard—hardly an incentive to enter into or persist in the profession. However, in 1985 only 25% of teachers surveyed by Metropolitan Life cited lack of respect among the factors that made them seriously consider leaving teaching, even though 74% acknowledged that prestige was higher in their alternative occupational choice. Harvey and Marsden (this volume) discuss how teaching has historically been an avenue of social mobility.

Another social force, internalized values about teaching, may be the best magnet for drawing new teachers to the profession. Of the 985 teachers in the 1985 Metropolitan Life survey who had seriously considered leaving teaching, 74% said that job satisfaction was their main incentive for remaining. They specifically mentioned such factors as relationships with students, a love of teaching, and satisfaction in seeing students grow and progress.

"Economic forces" refers to the job market conditions that influence an individual's decision to teach. The economic picture for teachers is not terribly bright, and Peterson (this volume) is not alone in arguing that low salaries are the major deterrent to attracting more and better people to teaching, particularly in math and science where discrepancies between teacher salaries and industry salaries are greatest. In 1981-1982, Levin (1985) notes, bachelor's degree recipients in the biological or physical sciences could earn starting salaries in industry that ranged from $2,100 to nearly $11,000 more than in teaching. Both the public and the teachers agree that higher salaries might help to attract and retain talented teachers. Nearly 95% of the teachers polled said that a decent salary would work to keep good people in teaching, and nearly 80% believed that higher initial salaries would raise the quality of people entering the profession (Louis Harris & Associates, Inc., 1985). Almost 60% of the people who believed that their local school system had difficulty in getting good teachers blamed low salaries, and 61% of all respondents thought that pay should be increased to recruit more teachers in the event of a shortage (NEA, 1985).

Other factors are involved in the market. Working conditions are sometimes cited as a negative influence, particularly in comparison with other professional jobs. As sources of dissatisfaction, 41% of teachers polled in the Metropolitan Life survey named working conditions, including long hours, overcrowded classrooms, too much paper work, and too many nonteaching duties. Although it was not specifically cited 48% of these teachers also reported that science laboratories were less than adequate. Darling-Hammond and Wise (work in progress, cited in Darling-Hammond, 1984) report that those teachers with the best qualifications have the least tolerance for poor work conditions. The fact that private schools are consistently able to attract good teachers even though they pay less than public schools also suggests that working conditions are important to teachers. However, some working conditions associated with teaching, such as longer vacations and job security, are perceived as advantages (Louis Harris & Associates, Inc., 1985).

Other market forces include perceived career alternatives and the costs and benefits of education. Many people have blamed the exodus from teaching on the wider acceptance of women and minorities into other professions. If true, this trend threatens quality as well as quantity since the most able people are the ones who will move first. Education costs and benefits include the usefulness and applicability of college courses (education courses are widely perceived to be of limited use, even to teachers) and the financial costs of paying for a college education. High-paying jobs become more attractive when there are loans to be repaid.

The Science Teacher Supply

As mentioned, there are more than 100,000 people teaching at least one science class. Some are not qualified, but it is not likely that many of them will be involuntarily removed or reassigned, so they must all be considered part of the supply. For these teachers, continuing education may be the solution.

The more interesting factor in the equation leading to future supply is the rate at which new science teachers are being graduated. The statistics are not heartening. In 1981, 597 students earned bachelor's degrees in science education (Plisko, 1983, p. 188), a figure that is down 33% from 1971, indicating a precipitous decline in the number of people who are preparing to teach science. If there is good news, it is that this decline is actually *less* than the average decline for all education degrees (38.7%). Still, given that college enrollment *rose* by 28% over that same decade (Plisko, 1983), the decline in the proportion of science education degrees is even more dramatic. Pelavin and Reisner (1983) cite an unpublished analysis of data from an NSTA survey of placement offices that cites the number of students preparing to teach science in 1980 at 875. This higher number includes not just education majors but all students who completed student teaching. The NSTA data suggest that the decline in the number of students preparing to teach science is closer to 60%. There is evidence also that the number of students with the most extensive scientific training is falling most quickly: 90% fewer recipients of bachelor's degrees in physics became high school teachers in 1981 than in 1971 (35 in 1981 vs. 300 in 1971) (Ellis [1982], cited in Pelavin & Reisner, 1983). Additionally, there may be cause for future concern: annual surveys of high school seniors and college freshmen show a precipitous drop in the number of students who perceive teaching to be an attractive career (Plisko, 1983, pp. 219–220).

Not all students who prepare for teaching elect to teach. In 1981, 11% of students majoring in biological science education did not apply for a teaching job (Plisko, 1983, p. 190); the sample for physical science education unfortunately was too small to count. Shymansky and Aldridge (1982) show graphically that the proportion of student teachers who accepted teaching positions declined from approximately 60% in 1971 to 25% in 1980. The good news is that the proportion of acceptances is not declining as fast as the absolute number of students completing student teaching.

Increasing the Supply

If it can be ascertained that supply needs to be increased and by how much, how do we accomplish that? This complex problem has no single, clear answer. An increase in teacher salaries, both across the board and in particular for science and math teachers, is proposed most often as a remedy. Levin (1985) advances the case for paying qualified science teachers more than other teachers as a means of keeping up with the market for their talent. Peterson (this volume) outlines a similar case. Detractors point out that industry will probably be able to match such higher salaries and that they would simply cost too much. They also say that it would be unfair to pay some teachers more than others, which is the chief reason cited by the unions for their historic opposition to this proposal. Finally, they propose that an increased salary alone will not induce more people to teach, arguing that other factors such as working conditions and status are important to these teachers.

Levin (1985) has introduced an interesting twist into the debate on higher salaries. He suggests:

> The prodigious appetites of defense industries for technical and scientific talent has bid up the price of such persons even beyond the higher salaries they would receive in a market economy. . . .Given the well-known generosity of the federal government in funding defense contracts and

the lack of incentives for keeping down costs, the pay offers of such enterprises have probably been one of the most important influences in escalating salaries of scientists, mathematicians, and engineers. (p. 12)

This line of reasoning leads inescapably to a clear avenue of possible federal action that in no way would interfere with the states' rights to govern education: holding defense spending to moderate, well-monitored levels.

A second suggestion for attracting people to teaching is forgivable loans. This approach is already being tried in 28 states with mixed success (Rodman, 1985). Some states report that funds go begging while others report a surfeit of applicants. No one is sure what the eventual impact will be on teacher supply. Critics suggest that $5,000 loans are not difficult to repay, especially if the prospective teacher takes an industrial job that pays $7,000 more in the first year than a teaching position would.

One suspects that these economic remedies are advanced because the social ones are so much more difficult to engineer. Higher salaries and loans can be legislated; increased status cannot. It has been suggested that the status of teachers, and education in general, is relatively low because it is an occupation that is generally regarded as "women's work." Not only are most teachers women (although this is not true of science teachers), but education is sometimes regarded as an extension of the child care that in our society traditionally has been a woman's domain. Low status also becomes a self-fulfilling prophecy. The best students may be loathe to relegate themselves to what is perceived to be a lower-status position, particularly today when so much emphasis is on upward mobility and achievement; thus, the quality and status of the profession suffer even more.

The status of the profession is also tied into its working conditions. Some of this interaction is played out in Harvey and Marsden's discussion of the occupational status of teachers (this volume). This argument is that if teachers had more professional opportunities, both in their current working conditions and in their possibilities for advancement, teaching would be more attractive to brighter students. As an occupation, it would compare more favorably with the alternatives. This is the motivation behind the merit-pay and career-ladder proposals. Although merit pay in its current incarnation is opposed by the teacher unions as an arbitrary and unfair reward system, Albert Shanker, president of the American Federation of Teachers, recently endorsed a differential-pay system (Currence, 1985a). Educators have also been urged to take a lesson from business and allow more decisions to be made by individual teachers.

Conclusions

Is there a crisis in science teaching? Although the rhetoric of most reports is one of crisis, Levin's analysis of the meager national data[5] is that the so-called crisis condition has in fact been with us for many years (Levin, 1985). If one accepts Levin's interpretation—that a shortage of qualified physical science and mathematics teachers has existed for a long time—why has the situation persisted?

A partial answer lies in the social, economic, and political system in which science teaching is embedded. The system is complex, and the forces that drive it are not well understood. Since the system has never been systematically or empirically monitored, little is known about its natural changes or about the effects of past deliberate efforts to change it. Little reliable information about the existing state of the system is available, so there is no way to assess the effects of the many efforts now under way to improve it.

Is there a shortage of science teachers? The data are far from clear when the question is posed in this way. However, the public agrees that the existing quality of science teaching is less than optimal. Experts assert that efforts to meet rising public expectations will require significant rethinking of teacher qualifications and the ways in which they remain current in their scientific and pedagogical knowledge.

Is a crisis imminent? Several large city school districts began the 1985–1986 school year with empty classrooms. New York City, for example, reported a "critical" shortage of 4,200 teachers, which it is attempting to alleviate by luring retirees back and recruiting teachers from overseas (Rohter, 1985). Houston and Detroit also report shortages. There are local shortages of teachers in all content specialties and reason to believe that existing shortages of mathematics and science teachers will become more acute than shortages in other subjects. Observers point out that many science and math teachers will be retiring in the next ten years, thus compounding the other factors contributing to teacher shortages.

What actions should be taken? The answer depends partly on how we interpret the data and the signs. Is the challenge to change significantly the qualifications of the science teaching force to meet higher public expectations, or is it only to have just enough minimally qualified teachers to staff the nation's science classrooms? Even with clear objectives, it is difficult to determine the exact course of action needed. Short-term actions to improve science teaching will not be informed by adequate theory, will be difficult to monitor empirically, and will not

[5]There are national efforts under way to generate better definitions of science teacher quality and a more adequate data-base. Studies in the planning or data-gathering stages are being conducted by the National Academy of Science, NCES, NSF, Educational Testing Service (through the Science Test of the National Assessment of Educational Progress), and NSTA.

reflect a unified purpose for science education. The deficiencies that weaken our ability to determine the best courses of action can be remedied only by achieving consensus on the purposes of science education (see Graham & Fultz, this volume) and better understanding of the causal relationships among the elements of the larger system. What is the relationship between teachers' knowledge, their classroom behavior, and students' science achievement? How does a raise in science teachers' salaries affect the supply of teachers and the relationships of science teachers with their colleagues? These are two of the many interactions in the system that need to be better understood.

When can we expect to observe the results of our efforts? For all the reasons we have noted, changes in the educational system are likely to be slow. Actions to effect the changes will require constant monitoring and midcourse corrections. The effort is necessarily a long-term and cyclical one. It can be sustained only by instituting mechanisms to monitor the system and to ensure its function.

References

Adler, M. J. (1982). *The Paideia proposal.* New York: Macmillan.

Akin, J. N. (1984). *Teacher supply/demand 1984: A report based upon an opinion survey of teacher placement officers.* Madison, WI: Association for School, College, and University Staffing.

Boyer, E. L. (1983). *High school: A report on secondary education in America.* New York: Harper & Row.

Brophy, J., & Good, T. (1985). Teacher behavior and student achievement. In M. Wittrock (Ed.), *Handbook of research on teaching* (3rd ed.). New York: Macmillan.

Currence, C. (1985a, September 4). Unions: A campaign to "professionalize" teachers. *Education Week,* pp. 1, 32.

Currence, C. (1985b, September 25). Shortages of '85 vanish as schools hire uncertified teachers. *Education Week,* pp. 1, 16.

Darling-Hammond, L. (1984). *Beyond the commission reports: The coming crisis in teaching.* Santa Monica, CA: Rand Corp.

DeForge, Y. (1981). *Living tomorrow. . . An inquiry into the preparation of young people for working life in Europe.* Strasbourg, France: Council of Europe.

Dillworth, M. E. (1984). *Teachers' totter: A report on teacher certification issues* (Occasional Paper No. 6). Washington, DC: Howard University Institute for the Study of Educational Policy.

District court rules teacher must keep his certification. (1984, April 24). *Education Week*, p. 3.

Education Commission of the States. (1983). *A summary of major reports on education*. Denver, CO: Author.

Education Commission of the States Task Force on Education for Economic Growth. (1983). *Action for excellence: A comprehensive plan to improve our nation's schools*. Denver, CO: Education Commission of the States.

Eurich, N. P. (1985). *Corporate classrooms: The learning business*. Princeton, NJ: Carnegie Foundation for the Advancement of Teaching.

Feistritzer, C. E. (1983). *The condition of teaching: A state by state analysis*. Princeton, NJ: Carnegie Foundation for the Advancement of Teaching.

Frankel, M. M., & Gerald, D. E. (1982). *Projections of education statistics to 1990–91* (Vol. 2). Washington, DC: National Center for Education Statistics.

Futrell, M. H. (1985, August 28). News conference statement.

Galambos, E. C. (1985). *Teacher preparation: The anatomy of a college degree*. Atlanta, GA: Southern Regional Education Board.

Galambos, E. C., Cornett, L. M., & Spitler, H. D. (1985). *An analysis of transcripts of teachers and arts and sciences graduates*. Atlanta, GA: Southern Regional Education Board.

Gerlovich, J. A., & Howe, T. G. (1982, March). Where the jobs are. *The Science Teacher*, pp. 56–59.

Goodlad, J. (1983). *A place called school: Prospects for the future*. New York: McGraw-Hill.

Grant, W. V., & Snyder, T. D. (1983). *Digest of education statistics 1983–84*. Washington, DC: National Center for Education Statistics.

Griesemer, J. L., & Butler, C. B. (1983). *Education under study: An* *analysis of recent major reports on education.* Chelmsford, MA: Northeast Regional Exchange, Inc.

Helgeson, S. L., Stake, R. E., Weiss, I. R., et al. (1978). *The status of pre-college science, mathematics, and social studies educational practices in U. S. schools: An overview and summaries of three studies.* (Report No. SE 78-71). Washington, DC: National Science Foundation.

Hirsch, C. R. (undated). *A profile of Michigan teachers of high school biology, chemistry, and physics: 1980–83.* Unpublished manuscript.

Hodgkinson, H. L. (1985). *All one system: Demographics of education, kindergarten through graduate school.* Washington, DC: Institute for Educational Leadership, Inc.

Hurd, P. D. (1984). *Reforming science education: The search for a new vision* (Occasional Paper 33). Washington, DC: Council for Basic Education.

Klein, S. E. (1982, May 24). Testimony before the Subcommittee on HUD-Independent Agencies of the Senate Appropriations Committee.

Levin, H. M. (1985). *Solving the shortage of mathematics and science teachers* (Project Report No. 85-A2). Palo Alto, CA: Stanford University, Institute for Research on Educational Finance and Governance.

Louis Harris & Associates, Inc. (1985). *The Metropolitan Life survey of the American teacher 1985: Strengthening the profession.* New York: Metropolitan Life Insurance Co.

National Commission on Excellence in Education. (1983). *A nation at risk: The imperative for educational reform.* Washington, DC: Author.

National Education Association. (1985). *A Gallup survey on education.* Unpublished manuscript.

National Science Board Commission on Precollege Education in Mathematics, Science, and Technology. (undated). *Educating Americans for the 21st century: A plan of action for improving mathematics, science and technology education for all American elementary and secondary students so that their achievement is the best in the world by 1995.* Washington DC: Author.

National Science Foundation Office of Scientific & Engineering Personnel & Education. (1982). *Science and engineering education: Data and information* (NSF 82-30). Washington, DC: National Science Foundation.

Panel on Secondary School Education for the Changing Workplace of the Committee on Science, Engineering, and Public Policy. (1984). *High school and the changing workplace: The employers' view.* Washington, DC: National Academy Press.

Pelavin, S. H., & Reisner, E. R. (1983). *An analysis of the national availability of mathematics and science teachers.* Washington, DC: Education Analysis Center for Educational Quality and Equality.

Peoples, J. A. (undated). *The exodus of blacks from the teaching profession in Mississippi.* Unpublished manuscript.

Peterson, P. E. (1983, Winter). Did the education commissions say anything? *The Brookings Review*, pp. 3–11.

Plisko, V. W. (Ed.) (1983). *The condition of education* (1983 ed.). Washington, DC: National Center for Education Statistics.

Ravitch, D. (1983). *The troubled crusade: American education, 1945–1980.* New York: Basic Books.

Rodman, B. (1985, September 4). Forgivable loans: Their success is mixed, future is unsure. *Education Week*, pp. 1, 34.

Rohter, L. (1985, August 11). New York schools facing a shortage of 4,200 teachers. *The New York Times*, pp. 1, 34.

Roth, R. A., & Mastain, R. (Eds). (1984). *Manual on certification and preparation of educational personnel in the United States.* Sacramento, CA: National Association of State Directors of Teacher Education and Certification.

Schwartz, A. E. (1985, September 5). Pedagogy and PR. *The Washington Post*, p. A21.

Shymansky, J. A., & Aldridge, B. G. (1982, November). The teacher crisis in secondary school science and mathematics. *Educational Leadership*, pp 61–62.

Sizer, T. R. (1984). *Horace's compromise: The dilemmas of the American high school.* Boston: Houghton Mifflin.

Smith, M. S. (1984). *Educational improvements which make a difference: Thoughts about the recent national reports on education.* Washington, DC: Federation of Behavioral, Psychological, and Cognitive Sciences.

Twentieth Century Fund Task Force on Federal Elementary and Secondary Education Policy. (1983). *Making the grade.* New York: Twentieth Century Fund.

Welch, W. W., Harris, L. J., & Anderson, R. E. (1984, December). How many are enrolled in science? *The Science Teacher,* pp. 14–19.

ECONOMIC AND POLICY TRENDS AFFECTING TEACHER EFFECTIVENESS IN MATHEMATICS AND SCIENCE

Paul E. Peterson
The Brookings Institution

Introduction

Today's American students learn less in mathematics and science. They learn less than do their counterparts in many other industrialized countries. They learn less than they used to, and they have less exposure to these subjects than to reading and the language arts. When facing the cultural divide between the sciences and the humanities of which C. P. Snow wrote, Americans have generally avoided the sciences.

The reasons for this choice are deeply rooted in American culture. America is an ethnic melting pot which is homogenized by common instruction in the English language and by studies of the heroic achievements of the founding fathers. America is an egalitarian society in which everyone stands on equal footing and in which verbal acuity and personal expression count for much in making one's way in the world. The American economy runs by the principles of the marketplace, an arena that demands high-level bargaining and negotiating skills.

In such a society the science and math curricula take second place. The structural hierarchy of scientific propositions, the certainty of mathematical equations, and the rigidity of algebraic formulas are difficult to integrate into a pluralistic, competitive society. Such precision better suits the vertical order of Japanese or European societies than the ceaseless spontaneity that characterizes the United States. Very few American heroes are scientists, and those that were—Benjamin Franklin, James Watt, and Thomas Edison—were amateurs or inventors whose works hardly constitute model applications of the scientific method. The only great scientist or mathematician who has captured the imagination of the American public—Albert Einstein—was a European import.

If the remote sources of scientific illiteracy in America are cultural, other, seemingly more tractable, proximate ones can also be identified within our educational system. Most notably, science and mathematics teachers are more difficult to recruit and harder to keep than are their history and English counterparts. This chapter examines ways in which we might enhance the learning of science and mathematics by considering alternative ways of enhancing teacher effectiveness in these subject areas. One simple way to upgrade mathematics and science teaching is to offer these teachers better salaries than teachers normally receive. Since schools cannot attract qualified science and math teachers at current salary levels, they should increase the rewards for teaching these subjects so that well-qualified teachers could be recruited. However, this simple solution is seldom even proposed, emphasizing the extent to which the problem is cultural and political rather than substantive. For decades, teachers have been paid according to a single schedule, which distinguishes salaries only according to teachers' years of experience and level of education. Now that teachers have the right to engage in collective bargaining, it is virtually impossible to reintroduce systematic pay differentials into the education system.

Because the basic issue of differential salaries is politically taboo, more palatable recommendations are offered. These include proposals for "merit pay," student loans for prospective teachers, inservice training, extended preservice training, and career recognition. Although all these proposals seem meritorious, they are likely to have little substantive impact and may actually have perverse consequences if teacher salaries remain as they are. The same is true of the recently passed Education for Economic Security Act.

In this chapter, I first examine the changes in U.S. performance in science and mathematics knowledge and competence. Then, recent trends in teacher supply, demand, quality, and compensation are reviewed. Next, the political difficulties associated with differential pay scales are assessed. Finally, the recent efforts designed to enhance teacher effectiveness are evaluated.

Student Performance in Mathematics and Science

American students are performing less well in mathematics than their counterparts in many other industrialized countries. This was first observed some 20 years ago when the first comprehensive international study of mathematics achievement, the International Assessment for the Evaluation of Educational Achievement, revealed that the average performance by U.S. eighth-grade students ranked 11th out of 12 (Husen, 1967). The U.S. mean ranked only ahead of Sweden and more than one standard deviation below that of the Israeli and

Japanese students, who achieved by far the highest score. American students scored even more poorly in 12th grade, although the meaning of this result is unclear because the percentage of an age cohort in secondary school at age 17 varies substantially among countries.

The situation has not noticeably improved since then. In a repeat survey, this time extended to 21 countries, the results are nearly the same (Travers & McKaight, 1985). Although detailed findings will not be released until 1986, preliminary results show that the U.S. median score actually declined from its comparatively low 1964 level—from 48% to 45% correct answers with the steepest fall occurring "on items requiring higher cognitive skills, rather than on items requiring computational skills" (Travers & McKaight, 1985, p. 412). The new U.S. median is still below the international median score in geometry and measurement and just at the median in arithmetic, algebra, and statistics. Although the United States is no longer near the bottom of the list, little heart can be taken from this finding. With the inclusion of nine additional countries in the survey, as many as a third of the countries were developing nations such as Hong Kong, Nigeria, and Swaziland, which do not have anywhere near as many resources to sustain an educational system as does the United States.[1]

The Education Commission of the States (1979, 1983) also reports that mathematics performance declined among 9- and 17-year-old Americans, although the performances of the 13-year-olds improved during the decade. Table 2, which shows the average performance of U.S. students on math and science exams from 1970 to 1982, reveals that the largest decline occurred in the mid-1970s. These findings are consistent with changes in scores of high school seniors on the quantitative component of the Scholastic Aptitude Test (SAT). Student performances fell by 20 points on the mathematics component between 1966 and 1976, but there has been only a one-point decline between 1976 and 1984 (College Entrance Examination Board, 1984).

Student performance in the sciences is different enough from math performance to warrant separate treatment. The first international comparison of student achievement, the International Assessment for

[1]At the 12th-grade level the United States did even worse—on no test did its average come close to the international median. Instead, it typically scored in the bottom 25%. Given the wide international disparities in the percentages of the population studying an academic curriculum in high school, one should not give too much weight to the 12th-grade findings. It is likely that the low average score in the United States is due to broader student participation. Yet the data do not give us much hope that the deficiencies evident at the eighth grade are remedied in the high school years. However, the U.S. 12th-grade score increased by an average of six points since 1964. But it is not clear that the sample for the 12th grade was drawn the same way in 1982 as in 1964; inasmuch as this finding is inconsistent with other findings on high school achievement discussed below, it should be discounted until methodological details from this study become available.

Table 2

Change in average performance of United States students on mathematics and science examinations.

	Mathematics		*Science*		
	1973-78	*1978-82*	*1970-73*	*1973-77*	*1977-82*
Nine-year-olds	−0.7	−0.2	−1.2	−0.1	0.9
Thirteen-year-olds	−1.5*	4.2	−1.7	−0.7	−0.1
Seventeen-year-olds	−2.9	−0.3	−2.8	−1.9	−1.7

Note: Sources of data are Education Commission of the States (1978, 1979, 1983) and Minnesota Research and Evaluation Center (1983).

the Evaluation of Educational Achievement, was conducted in 1970. On that test, administered to 10-year-olds, 14-year-olds, and high school seniors, the United States scored second among the youngest group and at the median (seventh out of 13 countries) among the 14-year-olds. U.S. scores were at the bottom of this list among high school seniors, but once again that was because the United States had a higher percentage of the age cohort taking the examination than did any other country (Comber & Keeves, 1973). Only preliminary reports from the recent 1983 international study have been released and we cannot be sure about the reliability and validity of these findings, but the data suggest that U.S. students know more science at both ages 10 and 14 than their counterparts did in 1970 (Jacobson & Doran, 1985). Other data (Education Commission of the States, 1978, 1979, 1983) are not consistent with these findings (Table 2). They show steady declines among both elementary and secondary students over roughly the same period, including bigger declines among 17-year-olds.

Changes in Teacher Quality and Compensation

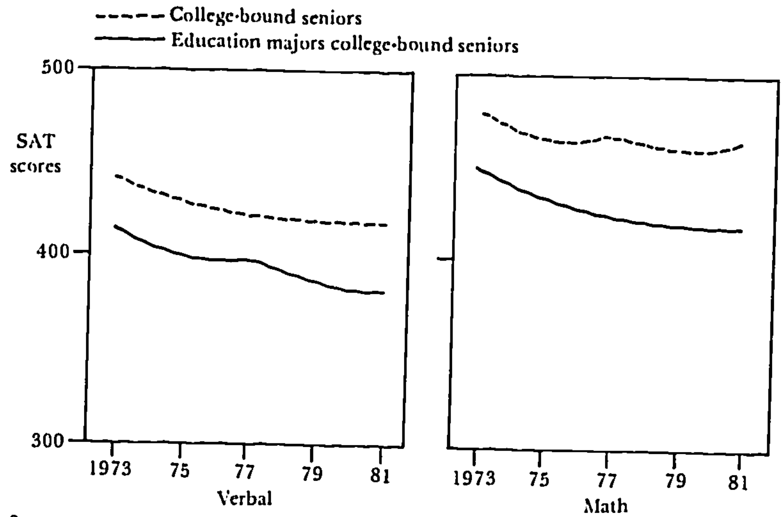
It is difficult to specify the extent to which performance in mathematics and science, particularly among the high school students, is influenced by characteristics of American classrooms. Much learning takes place in nonschool settings: in families, among peers, and via the media. Many nonschool factors, such as the increased number of single-parent families, the prevalence of drug use among adolescents, and the sheer magnitude of the task of absorbing the baby boom into the social fabric, could account for a decrease in this learning. But if the recent decline in educational performances can be attributed to nonschool factors, it is equally true that various changes in U.S. schools seem to have weakened the nation's ability to educate young people in mathematics and science. Among other things, the shortage of science and mathematics teachers, always a critical problem in American education, has worsened in recent years.

Teacher Supply

When university placement officials are asked to estimate the balance of supply and demand for teachers in various subject areas, they have for more than a decade identified mathematics, physics, and chemistry as being among the areas of greatest shortage. Further, the shortage of science and math teachers today is perceived to be 14% greater than it was a decade ago.[2] As a result, science and math courses are often taught by teachers who have only modest college preparation in these subjects. According to one study, in the state of Washington 36% of high school mathematics classes were taught by teachers who had neither a major nor a minor or its equivalent in the field. For physics and chemistry the percentages were 43%; for geography, 92%. At the junior high school level, these percentages were much higher (Pierce, 1985).

Even though shortages are growing more severe, young people are less attracted to teaching mathematics than they used to be. Between 1971 and 1981 the percentage of education majors graduating from college fell by 39%. The decline, however, was uneven among the fields. The percentage decline in physical education was only 23 and in drivers' education only 17, but the drop in mathematics was a whopping 64% (Feistritzer, 1983). Moreover, even when college students earned a math education degree, they did not necessarily become teachers. In 1978, 22% of college graduates with degrees in mathematics education did not apply for a teaching position, 1% less than the average for all education majors. By 1981 the percentage of math education majors deciding against entering the field had increased to 27% even when the national average for all education majors was falling to 15%. In other words, changes in both the numbers of people seeking training in math education and in their career choices have aggravated the math teacher shortage.

[2]The average shift on a 5% scale was 0.69 or 14% (Akin, 1985). Rumberg (1984) argues that there is no conclusive evidence that the teacher shortage in these subject areas has grown worse in recent years, and that the "potential" supply of these teachers is enough to cover the need. The paper is correct in criticizing exaggerated claims, but "potential" supply of trained people will not become an "actual" supply unless teacher salaries are competitive with those offered in other fields.



Source: Linda Darling-Hammond, *Beyond the Commission Reports: The Coming Crisis in Teaching* (Santa Monica, California: Rand, 1984), p. 2.

Figure 4

Academic ability of prospective teachers is declining.

The growing shortage of science and math teachers has been accompanied by a general decline in the academic quality of students planning to major in education. This was initially observed in a study of the SAT scores of North Carolina high school students. As shown in Figure 4, the decline in their SAT scores was even steeper than for college-bound seniors generally. A recent nationwide study has confirmed these findings:

> In 1973 high school seniors intending to major in education in college scor [illegible] points below the national average on the verbal portion [illegible] the SAT and 32 points below on the mathematics portion. By 1982, the gap between the average scores of the college-bound education majors and the national averages had widened to 32 points on the verbal portion and 48 points on the mathematics portion of the SAT (Feistritzer, 1983, p. 88).

The data pertain only to students planning to become teachers, not to those already teaching. Other evidence indicates that the abilities of the teaching force itself have declined slightly. According to a survey by the NORC, the verbal ability score of the average teacher declined from 77% to 74% between the mid-1970s and the 1980s (as compared with an average score of 60% for Americans in all other occupations, a figure that remained constant over this period).[3]

Teacher Compensation

These changes in teacher quality are consistent with what one might expect from changes in teacher salaries over the past decade. As shown in Table 3, salaries, in real dollars, fell from $23,334 to $20,432 between 1970 and 1983, a decrease of some 12%. (The drop from 1972 to 1982 was 22%.) This decline is understandable because the teacher market changed from one of scarcity to one of oversupply. By the late seventies, the number of new graduates exceeded the demand for them. At the very time the baby boomers were graduating from college, the baby bust generation was in grade school. Trying to keep teacher salaries high when supply increased and demand decreased would have defied the laws of the marketplace.

In the process of adjusting to new market conditions, teacher salaries declined relative to salaries of employees in other occupations. Whereas teachers in 1970 received about 20% more than the average employee in all industries, that percentage fell to 14% in 1983 (see Table 3). Teaching had become financially less attractive to college graduates.

As teacher salaries fell to new lows, demographic trends reversed direction. The baby bust generation is now entering college and if the percentage of college graduates entering teaching remains at current levels, the numbers of new teachers will fall (see Figure 5). At the same time that the supply of teachers is declining, the demand is growing. A new baby boomlet, the children of those baby boomers who are now in their child rearing years, are entering elementary school. Elementary enrollments, which have been stable for the past few years, are expected to increase by more than 10% by 1990 (Table 4). Although these increases will be offset somewhat by declines at the secondary level, the overall demand for teachers now is intensifying for the first time in more than a decade.

Given these changes in demography, teacher salaries will have to increase if teacher quality is not to fall precipitously. However, few recognize the size of the increments that are needed. First, salaries

[3]NORC surveyed the verbal ability of the American public in 1974, 1976, 1982, and 1984. Data for the first three surveys was merged and compared with the merged file for 1982 and 1984. The number of cases for teachers was 189 for the three surveys taken in the 1970s, and 104 for the two surveys conducted in the 1980s. For the other occupations the number of cases was 3,668 for the 1970s and 2,542 for the 1980s. (Information provided to author by Thomas Smith, Director, General Social Survey, NORC, University of Chicago, Chicago, IL.)

Table 3

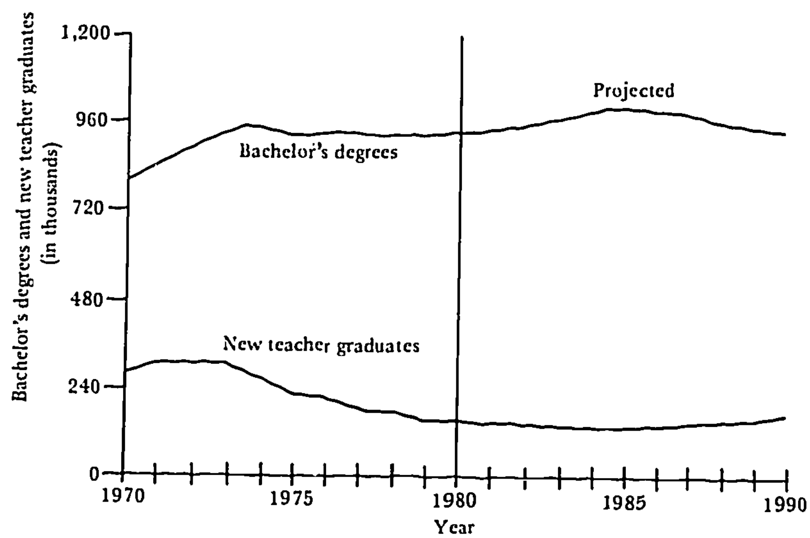
Average annual salaries for elementary and secondary school teachers as compared with those for full-time employees in all industries.

	Teacher salary (dollars)		Industry		Percentage higher teacher salaries than industry salaries
	Current	Constant	Current	Constant	
1929-30	$ 1,420	$ 8,366	$ 1,386	$ 8,165	2.4
1939-40	1,441	10,287	1,282	9,152	12.4
1949-50	3,010	12,518	2,930	12,186	2.7
1959-60	5,174	17,545	4,632	15,707	11.7
1969-70	8,840	23,334	7,334	19,358	20.5
1979-80	16,773	21,546	15,094	19,406	11.1
1982-83	20,114	20,432	17,620	17,899	14.2

Note: Sources of data are National Center for Education Statistics (1983. p. 55) and National Education Association (1983).

[a]1983 = 100

[b]Preliminary data



Source: U.S. Department of Education, National Center for Education Statistics, *Projection of Education Statistics to 1990-91* (Washington, D.C.: GPO, 1982) p. 76.

Figure 5

Bachelor's degrees and supply of new teacher graduates, 1969–70 to 1990–91.

Table 4

School age population, 1960–1990 (in thousands).

	5-13-year-olds	*14-17-year-olds*
1960	32,965	11,219
1970	36,636	15,911
1980[a]	30,199	15,764
1985[a]	29,098	14,392
1990[a]	32,568	12,771

Note: Source of data is Bureau of the Census (1980).

[a]Projected.

must increase by 4% or 5% a year merely to keep pace with inflation. Second, increases of 2.5% a year beyond that amount are probably necessary if teacher salaries are to remain competitive with those in industry. Such an increase will be necessary if productivity in the U.S. economy as a whole improves by 2–3% per annum and if workers realize those productivity gains in increases in real wages. The Reagan administration optimistically predicts a 4% growth in productivity over the next five years (Council of Economic Advisors, 1985). If this prediction is accurate, teacher salaries will have to increase by an even higher rate to remain competitive. But even if we use a more conservative estimate that most economists employ, teacher salaries, in order to stay on par with those in other occupations, must increase, on average, to $26,700 in real dollar terms or $38,800 in current dollar terms by 1990 if inflation averages 5% per annum through the rest of the decade (see Table 5).

Table 5

Average annual salaries of elementary and secondary public school teachers.

	Current dollars	*Constant dollars*[a]
1929-30	1,420	8,366
1939-40	1,441	10,287
1949-50	3,010	12,518
1959-60	5,174	17,545
1969-70	8,840	23,334
1979-80	16,773	21,564
1985-86	27,555[b]	24,180[b]
1990-91	38,828[b]	26,696[b]

Note: Source of data are National Center for Education Statistics (1982, 1983) and National Education Association (1983).

[a]1983 = 100

[b]Estimated figure. An inflation rate of 5% is assumed.

Third, salary increases higher than these will be necessary if schools are to attract more than the current 17% of college graduates necessary to teach the larger number of elementary school pupils anticipated by 1990 and to offset the increased rate of retirement expected in the next few years. In addition, still larger salary increments will be necessary to attract better quality personnel to teaching. It is difficult to specify the exact percentage by which salaries will have to increase. If they are to regain the same competitive edge vis-à-vis other occupations that they had achieved in 1970, they will have to reach $28,400 in real dollars or $41,300 in 1990 dollars. In short, if teacher salaries are to keep up with inflation, to keep up with expected salary increases in other occupations, and to regain their competitive standing as of 1970, the 1982-1983 salaries will need to double in nominal terms by the end of the 1980s.

Unfortunately, even with the current wave of reform, such a dramatic turnaround is unlikely. Americans would have to more than double their nominal spending on public elementary and secondary schools from $104 billion in 1981 to $265 billion by 1990, an increase of 36% in real dollar terms, or by 4% a year over and above the cost of inflation (Table 6).

Table 6

Percent of the gross national product spent on public elementary and secondary education, 1949–1985 (billions, unadjusted dollars).

	GNP (dollars)	*Expenditures (dollars)*	*% of GNP*
1949	258.0	4.7	1.8
1959	486.5	12.3	2.5
1969	935.5	34.2	3.7
1975	1,528.8	62.1	4.1
1979	2,395.4[a]	87.0[a]	3.6
1981	2,954.1[b]	97.0	3.3
1982	3,073.0	112.6	3.7
1985	3,947.0[c]	133.0[d]	3.4
1990	5,666.4	265.0	4.7

Note: Sources of data are National Center for Education Statistics (1983, pp. 80-81; 1982, p. 104). Projected gross national product from George Perry (Brookings Institution, Washington, DC).

The school year beginning in September of the listed year.

[a]Based on 1978 GNP of $2,106.6.
[b]Based on 1980 GNP of $2,626.1.
[c]Projected, Brookings Institution.
[d]Projected, Department of Education using projected Consumer Price Index.

Americans have done this in the past. Between 1949 and 1975 the percentage of the gross national product allocated to the public schools was more than doubled (Table 6)—from 1.8% in 1949 to 4.1% in 1975. However, between 1975 and 1982 it fell to 3.6%, a function of declining numbers of pupils and of decreasing teacher salaries. We might return to our previous performance, but the gains in the 1950s and 1960s occurred when the public seemed prepared to accept a shift in expenditures from the private to the public sectors. Now that cutting taxes is politically popular, it is difficult to see how real expenditures for public education can grow by a rate equivalent to that of the 1950s and 1960s.

Such a rapid growth in educational expenditures is necessary if the United States is to maintain, or marginally improve, its existing teaching force. Because education competes with other industries for its personnel, a decline in teachers' salaries means a decline in the quality of those attracted to education.

These changes in teacher quality do not happen precipitously. In the short run, compensation levels can rise or fall markedly, without any apparent effects on performance. Many people working in a declining industry have already so committed themselves to that particular occupation that they cannot readjust without great personal and financial cost. One of the fallacies of the sixties was to expect immediate results in educational performance as a function of increased resource commitments to education. The reverse fallacy is invoked; whenever people do not see immediate institutional decline as revenues become more scarce, they conclude we can get by with less. But over the long run, changing compensation levels will have their effects. Young people making their first occupational choice can be expected to choose the more rewarding career. Many people in education have discovered early in their careers the advantages of switching to more lucrative lines of activity. This will happen with even greater frequency in a future of declining relative salaries. In these and countless other ways, marginal shifts in occupational choice can be expected to have a slow but steady impact on the quality of the teaching profession. As Albert Shanker, president of the American Federation of Teachers, has so aptly observed: "Without adequate salaries to attract talented people, it will be difficult to turn this trend [in teacher quality] around and, though we realize that the billions required to make teachers' salaries competitive are not likely to come from the federal treasury, this problem will hamstring any effort to solve the shortage."[4]

[4]Senate Hearing 98-251, *Education for Economic Security Act.* Hearings before the Subcommittee on Education, Arts, and the Humanities at the Senate Committee on Labor and Human Resources, 98th Cong., 1st Sess. (GPO), p. 316.

Differential Salaries for Math and Science Teachers

If the United States will have difficulty increasing the salaries of all teachers to the level needed to just maintain teacher quality, the problem concerning math and science teachers is much worse. Even during the golden age of the American teacher (the early 1970s), beginning teacher salaries were 25% less than those for chemistry majors and 23% less than those for graduates specializing in math or statistics. (By comparison teacher salaries were only 12% less than those of liberal arts majors.) However, by 1982 the comparative prospects for teachers were even worse. Teacher salaries were 35% less than those of chemistry majors, 31% less than majors in math and statistics, 17% less than liberal arts majors. The outlook for all teachers was bleak, but the math and science teacher was asked to make the greatest financial sacrifice.[5]

To any businessman, the obvious solution is to pay science and math teachers higher salaries. At the university level such pay differentials among fields of study are accepted practice. For example, male university employees holding a doctorate in science and engineering earned an average of $34,800 in 1981, male social scientists earned $30,900, and male humanities teachers received, on average, $26,300, or 25% less than the scientists. For women, the salaries were $27,100, $26,000, and $23,200, respectively, or 14% less for humanities women compared with scientific women (National Research Council, 1982). When starting salaries at state universities for assistant professors are compared, similar differentials appear. In 1981–1982, physicists were offered an average of $20,130, mathematicians $19,870, and biologists $19,640, while social scientists were given but $18,730 and humanities teachers but $17,590 ("Surprises and uncertainties," 1982). Here the spread between physics and humanities teachers is only 13% because differences in initial starting salaries understate the long-term differences in career opportunities across fields. Nonetheless, if we select a figure between the highest and lowest differentials apparent in higher education, *science and math educators need to be paid 20% more than their counterparts in other fields, if equally qualified personnel are to be recruited.*

Political Obstacles to Salary Differentials

The political obstacles to differentially high salaries for math and science teachers are well-known. For decades school districts have paid all their teachers the same salaries regardless of their subjects pedagogical sophistication, or assigned grade level. Before World War II, elementary school teachers were paid less than secondary school

[5]Data calculated from Feistritzer (1983, p. 73, Table 4).

teachers, and until a Supreme Court decision (*Davis v. Atlanta Board of Education*) outlawed the practice in 1943, the salaries that Southern schools paid to black teachers were much less than those paid to white teachers. Both forms of discrimination have now disappeared.

Since salary differentials in the past often involved race and sex discrimination, the unified salary schedule has become a sacrosanct component of the educational system. Teacher associations campaigned for a unified schedule long before they won collective bargaining rights. Now that collective bargaining is an integral part of the education establishment, it is difficult to imagine unions and associations acceding to any policy that undermines this practice. A unified schedule makes for an integrated set of union demands, and an integrated set of demands is the key to teacher unity. Few policy proposals are more threatening to a union organization than those that seek to distinguish among its members. Instead, teacher organizations emphasize those characteristics that all teachers have in common. In the words of one National Education Association (NEA) report:

> All teachers perform the same basic function in their jobs. Teaching is based on a core of educational principles and calls for its practitioners to use similar skills—whether they happen to be art or history or science teachers. NEA believes, then, that teachers' salaries should be based on the formal level of professional preparation and teaching experience, not on the teachers' sex or race or even the subject or grade level taught.
>
> Paying math and science teachers on a higher salary scale suggests that those academic disciplines are more important than other subjects. Even the scientific community would hesitate to make such an arrogant and pedagogically unsound assertion (U.S. Senate, 1983, p. 307).

Of course, a single salary schedule does not mean that all teachers receive the same pay. Experience remains an acceptable basis for distinction, probably because it is easily measured, everyone can aspire to the highest rank, and union activists often come from among the experienced career teachers. Some evidence suggests that students learn somewhat more from more experienced teachers, although no additional gain has been found from teaching experience that exceeds five years (Hanashuk, 1981). Salaries also differ by degree of educational attainment. Once again this distinction is easily measured and is open to all. Also, it would seem oxymoronic if educators did not recognize the value of more education, though few, if any, studies have shown that students learn more if their teacher has a Master's rather than a Bachelor's degree (Hanashuk, Fall 1981).[6]

[6]See also Murnane (1981, Fall).

Apart from educational attainment and years of experience, school districts generally pay all their teachers the same salary. Systematic differentiation among teachers according to the subject they teach remains antithetical to local practice and anathema to teachers, 75% of whom expressed opposition to such an idea in a recent Gallup poll (A. Gallup, 1984). Even the public is evenly divided (48% to 49%) between supporters and opponents of "higher wages" for "teachers in science, math, technical subjects, and vocational subjects" in which shortages are the greatest (G. Gallup, 1984).

Recently, the idea of merit pay has been endorsed by the Reagan administration as a way of encouraging and motivating the best teachers. A few states, notably Tennessee, have set up programs designed to initiate some pay differentiation based on teacher accomplishment. Not surprisingly, teacher associations and two-thirds of all teachers have objected mainly on the grounds that identification of quality teachers is highly subjective, is open to administrative abuse, and would create morale problems in schools (A. Gallup, 1984). Public opinion is more supportive (65% favor merit pay), but this hardly represents a groundswell of support. Many people (45%) have neither read nor heard of any of the trial programs some states have initiated (G. Gallup, 1984).

Apart from the political objections, merit pay cannot adequately address the problems of mathematics and science education. The problem in this field is not that its teachers are of such high quality that they deserve "merit pay." In all probability, the science and math teachers left in the public schools after industry has attracted the ambitious ones are below-average teachers. The issue at hand is attracting and keeping more and better teachers; to accomplish this goal, *higher salaries must be paid to math and science teachers who are no better than their English, social studies, or elementary school colleagues.* This may seem contrary to many educators' view of the just wage, or comparable worth, but it is nonetheless the market reality.

Policy Proposals

Policy analysts are frequently called on to propose politically feasible solutions to widely perceived social problems. Often the appropriate response is obvious, but they cannot propose it because it is not politically palatable. Either the proposal is too expensive, too threatening to powerful interests, or too disruptive to established practice. Instead, various proposals advanced that seem to address the problem and that can attract a fairly broad base of support are advanced. Too often these proposals, if adopted, fail to work as they were intended: They are too small to respond to a large problem, they are too indirect, or they have secondary consequences that undermine the very objectives they were expected to achieve.

That, I'm afraid, is the probable consequence of many of the current efforts to strengthen math and science education. The most notable undertaking is the one enacted by Congress in 1984, the Education for Economic Security Act (EESA) funded in fiscal year 1985 to the tune of $100 million. It is a striking congressional initiative. It is a new intergovernmental grant program at a time when existing programs are being curtailed or eliminated. It is a categorical program that gives a new set of instructions to state and local officials at a time when deregulation of federal programs is in vogue. It commits the federal government to a new role in education when the Reagan administration says that it wants to take the government off the backs of local school officials. Finally, it is similar in form to many state initiatives to upgrade teacher quality. This federal legislation is thus not only intrinsically significant but it raises many of the same issues that also need to be discussed in conjunction with a variety of similarly designed state programs.

The purpose of the Act is "to provide additional resources for necessary efforts to increase the quality of mathematics and science instruction" (U.S. Senate, 1983, p. 9). To achieve the objective, its key section, Title II, grants monies to state agencies to improve the training and retraining of existing teachers and to institute *traineeships* for prospective teachers. Under certain circumstances some of the money can be used to purchase "instructional materials and equipment related to science and math" (U.S. Senate, 1983, p. 13). The state is to give 70% of the money to local school districts and 30% to teacher training programs in colleges and universities. To receive this money, states and local school districts must describe their current situation in math and science, project developments over the next five years, and describe programs undertaken to ameliorate these needs. The National Institute of Education is asked to conduct an annual evaluation of the implementation of the legislation.

The program seems to be a plausible, if modest, response to inadequate instruction in science and math. It promises tens of millions of dollars to train more teachers for these areas. But as welcome as the program may seem, its impact is likely to be miniscule if not counterproductive. First, there is little evidence that training facilities in math and science education are overburdened. Indeed, with the declining numbers of graduates in these fields and with declining enrollments in many colleges of education, there is probably an excess of training personnel. Also it is not clear that the amount of in-service training that teachers now receive is inadequate.

Even if the program were to increase the knowledge and skill of math and science teachers, students might not benefit. Teachers who seek additional training may only wish to enhance their attractiveness to nonschool employers. The better their math and science training, the more likely they are to follow their many colleagues for better paying jobs elsewhere.

What is true of in-service training is even more true of preservice education. Both the federal traineeships and a variety of state-sponsored student loan programs with forgiveness clauses for prospective math and science teachers are seeking to enhance quality by subsidizing teacher education. The program will benefit many young people who are planning to become teachers, but after they graduate many may decide that forgiveness of a $2,500 a year loan (the maximum amount provided by Tennessee) does not offset the value of a higher-paying job in industry. And even if graduates teach for a limited period while the loan is being forgiven, the young, poorly-paid teacher has every incentive to leave the profession once the loan has been paid. In short, federal, state, and local policies designed to increase teacher knowledge and skills in math and science without increasing their salaries are subject to a fatal flaw: Every attempt at improvement is fraught with the difficulty that the better trained scientist or mathematician will be more attractive to other employers. As a Republican minority report to the House of Representatives observed when this legislation was first proposed, "The way this bill is drafted might well increase [the exodus from teaching]. . .By increasing the skills of existing math and science teachers, without adopting a program to retain them in teaching, the temptation to leave teaching for the private sector becomes greater as those skills become more marketable" (U.S. House, 1983, p. 58).

In sum, despite its grand title, the EESA can hardly achieve its objectives because it is too small and too indirect a remedy to have much of an effect. In fact, its consequences could be quite the opposite of what was intended. Students of policy implementation who want to show that the Reagan administration cannot carry out a new intergovernmental grant-in-aid program any more effectively than did the Carter administration have in this legislation a golden opportunity to ply their research skills.

Earlier Federal Efforts to Improve Math and Science

Apart from the substantive focus of the EESA, it is doubtful whether any federal categorical grant aimed at enhancing math and science programs would have much effect. The federal role in education seems to work best when it focuses on segments of the population that are not adequately served by local school districts. Thus, the compensatory education program for low-income students and the special education program for the handicapped have had a positive impact and an administrative continuity that has transcended changes in national moods and party control (Peterson, 1983).

The National Defense Education Act (NDEA) of 1958, which the EESA resembles in both name and content, is another matter. A review of NDEA's legislative history and implementation should interest those who believe that the federal government can give much direction to those who want to enhance quality education.

Legislative History. The legislation focused on curricula for science, mathematics, and foreign languages. Although much of the legislation focused on the needs of higher education, Title III authorized funds for purchasing equipment and supplies and for minor remodeling of elementary and secondary schools (National Defense Education Act of 1958). Given the fanfare with which it was launched, the middle-class constituency it supposedly served, and its apparent relevance to the nation's defense, it is surprising that NDEA did not expand and develop throughout the next two decades in the way so many other educational programs did. Although it grew from a less-than-$53-million program in 1960 to a more-than-$75-million program in 1968, the NDEA allocation declined in subsequent years, falling to $29 million in 1976; in 1980, it was consolidated with other programs.

At the same time that expenditures decreased, the purposes of NDEA were becoming increasingly diffuse. In the beginning, support was limited to programs in science, mathematics, and foreign languages, but in 1964 Congress added programs in history, civics, geography, English, and reading; in the following year, programs in economics, the arts and humanities, and even industrial arts were included. Thus, the distribution of funds among subject areas altered dramatically between the early 1960s and the mid-1970s. As shown in Table 7, the percentage of funds allocated for the sciences dropped from 74% to 18% while those for reading and social studies, subjects that received nothing in early years, increased to more than 40% of NDEA allocations in 1976. By that time, almost any subject could have been said to be important for improving the defense of the nation.

This diffusion in its purpose made NDEA ripe for consolidation with other educational programs. Although Congress generally resisted the block-grant proposals of the Nixon administration, it agreed to consolidation when program purposes could not be clearly articulated and when supporting constituencies were weak. Because NDEA funds were used to purchase equipment and supplies for a wide variety of school subjects, there was little justification for its separate existence. Therefore, it was lumped with such programs as library services, guidance and counseling, and general aid to state departments of education.

NDEA's limited fiscal growth and diffuse purpose were caused partly by its lack of a well-defined, supportive political constituency. The

Table 7

Percent distribution of federal NDEA funds among subject areas.

Subject areas	*FY 1959-1962*	*FY 1976*
Science	73.8	18.2
Mathematics	8.6	9.0
Foreign languages	17.6	1.7
English and reading	—	26.7
Social studies	—	14.7
Arts and humanities	—	12.2
Industrial arts	—	9.1
Audio visual libraries	—	8.4
Total (in dollars)	$140,400,000[a]	$12,700,000[b]

Note: Sources of data are Office of Education (1963) and U.S. Office of Planning, Budgeting and Evaluation (1978).
[a]Paid by the Office of Education to the states and territories for equipment and minor remodeling up to June 30, 1962.
[b]"Program Acquisition" expenditures under NDEA Title III during fiscal 1976. These figures do not include expenditures made under ESEA, IV-B.

scientific community was more concerned with sustaining federal support for ongoing research than with training the next generation of scientists. Colleges and universities were abandoning their language requirements, thereby weakening the demand for foreign language instruction at the secondary level. Since NDEA funds were not to be used for teachers' salaries, neither the NEA nor the American Federation of Teachers (AFT) had a major stake in the program. Its only constituency was the school boards, school superintendents, and state departments of education that used NDEA monies to purchase materials and equipment.

Policy Implementation. The Office of Education prepared a 20-page form that explained to state education agencies (SEAs) how their proposed plans should be submitted for approval, but the requirements set forth were hardly stringent. Further, the U.S. Office of Education instructed its employees:

> . . .always remember that the States and local communities have primary responsibility for education and must retain full control over it. Therefore, do not construe any part of this Act to authorize you or any of your employees to exercise any direction over the curriculum, program of instruction, administration, or personnel of any educational institution or school system (U.S. Office of Education, 1959, p. 9).

Accordingly, the federal government proved very receptive to the state plans submitted. In the first year of the program, "More than 90% of the states had 90% or more of their requested projects, measured in dollar terms, approved" (Sufrin, 1963, p. 41). This high acceptance rate is particularly significant given the vague, general character of the plans. In the words of one well-informed observer, the SEAs "in their plans mostly stuck to bland and general descriptions of programs, priorities, and standards. Some came close to parroting the illustrations sent from Washington. . .No state intended to embarrass the Commissioner or to tie itself too closely to specifics" (Marsh & Gartner, 1963, p. 41).

The financial arrangements for distributing NDEA funds reinforced the tendency toward loose federal control. The distribution formula determined allocations among the states, but the SEAs were responsible for allocating funds among local school districts. Because funds were distributed on a 50% matching-grant basis, only local school districts or states that were willing to match federal funds participated. The matching-grant requirement also meant that a disproportionately high percentage of the funds went to larger wealthier districts that had greater administrative and fiscal resources(McDonnell et al., 1980).

Loose central control was coupled with lack of interest in substantive evaluation of the programs' effectiveness. To the best of my knowledge, no study of the effects of NDEA on student performances in science, mathematics, or any other subject area has ever been done. No record of any systematic, experimental research to identify the effects of any specific curricular materials purchased with NDEA funds exists. Any difference in student performances between schools that participated in the program and those that did not has yet to be determined. Although studies of this kind were not an integral part of government programs in the late 1950s and early 1960s when NDEA was established, when these studies became fashionable in the 1970s, they were not applied to NDEA. Instead, nonevaluation has been rationalized by the claim that "evaluation on a nationwide basis of any program is difficult since the necessary *before* bench marks are seldom available for comparison with the *after* results" (U.S. Office of Education, 1969, p. 17).

In sum, NDEA presents a puzzle for people who are considering federal education policy for the 1980s. The program provided general aid for an increasingly broad range of school activities; it did not focus on the needs of a specific constituency; it was administered in such a way as to give great autonomy and flexibility to local officials; and its operations were never formally evaluated. Some observers now believe that the program simply supplied materials and equipment that local districts would otherwise have purchased from their own funds (McDonnell et al., 1980). Although the program became in effect a block grant for local school districts, it seemed to have lost its sense of purpose and, with weak political support, was phased out in 1981. One possible conclusion is that if a federal program has no other purpose than to do what local school districts would do in any case, it has little reason for being. All it does is to add to the administrative complications of state and local officials. Any federal effort to enhance math and science education, therefore, must develop identifiable goals and constituencies that clearly supplement those of local school boards.

Conclusions

When the difficulties of improving math and science instruction are considered, the temptation is always to find the quick or easy solution. Three decades ago, when Sputnik was launched, it was thought that better equipment and supplies could revolutionize student learning. Two decades ago, well-known scientists and mathematicians thought that the solution lay in a new curriculum that met the high standards of the profession. Unfortunately, the new curriculum was often not used; or when used, was abused; or when used correctly, had uneven effects. Today the emphasis is on teacher education. All of the approaches discussed have some value, but none is likely to improve significantly U.S. scores on the international math and science examinations.

The characteristics and qualities of our schools are deeply embedded in our society and culture. The value we place on math and science cannot be altered overnight. Americans are committed to local control of their educational institutions. Fifty states and 20,000 school boards share authority over the future of the public schools. Such decentralization facilitates a community's consensus and accommodation to a pluralistic society filled with diverse religious, racial, and cultural groups, but such dispersion of authority precludes any rapid change in policy direction, even when national policy-makers are urging schools to do so.

The country needs clearer standards and expectations for the American high school. As it stands, the U.S. Department of Education eschews any responsibility for specifying the national curriculum, colleges and universities have diverse and imprecise standards for student admission, and the major national standard—the SAT—is resolutely free of substantive educational content. Indeed, it is ironic that the most popular measuring tool for evaluating high school students today is the SAT—a test originally designed to measure innate ability, not school achievement; a test that prides itself on being "content free"; one that a student cannot prepare for, except in a general way; and one that gives all students an equal chance, no matter what school they attend.

In a country without a uniform curriculum the only standard for measuring competence available is one for which a student cannot prepare. Thus, all efforts to raise standards must be indirect: by writing new curricula and hoping that teachers will adopt them; by calling for better textbooks and hoping that publishers will print them; and by calling for higher quality teachers and hoping that someone will train them. This indirect approach may be the only one consistent with American traditions, but, if it is, additional incentives must be used to attract the quality people necessary to create excellence in education. We can hardly expect to get better teachers for less money.

References

Akin, J.N. (1985, April 24). Teacher supply/demand by field and region. *Education Week*, pp. 12-13.

College Entrance Examination Board. (1982). *National report on college bound seniors*. Princeton, NJ: Educational Testing Service.

College Entrance Examination Board. (1984). *National report on college bound seniors, 1978-1984*.Princeton, NJ: Educational Testing Service.

Comber, L.C. & Keeves, J.P. (1973). *Science education in nineteen countries* (p. 159). New York: Wiley.

Council of Economic Advisers. (1985).Economic report of the President, p. 64. Washington, DC: U.S. Government Printing Office.

Darling-Hammond, L. (1984). *Beyond the commission reports: the coming crisis in teaching*. Santa Monica, CA: Rand Corp.

Education Commission of the States. (1978). *Three national assessments of science: changes in achievement, 1969-77*. (National Assessment of Educational Progress. Science Report No. 08-5-00). Denver, CO: Author.

Education Commission of the States. (1979). *Changes in mathematical achievement, 1973-78*. (National Assessment of Educational Progress. Report No. 09-MA-01). Denver, CO: Author.

Education Commission of the States. (1983). National assessment of educational progress, the third national assessment: Results, trends, and issues. Denver, CO: Author.

Feistritzer, C.E. (1983). *The condition of teaching: A state by state analysis.* Princeton, NJ: Carnegie Foundation for the Advancement of Teaching.

Gallup, A. (1984, October). The Gallup poll of teachers' attitudes toward the public schools. *Phi Delta Kappan*, p. 103.

Gallup, G. (1984, September). The 16th annual Gallup poll of the public's attitudes toward the public schools. *Phi Delta Kappan*, p. 34.

Hanashuk, E.A. (1981, Fall). Throwing money at schools. *Journal of Policy Analysis and Management*, *1*, 26, 28.

Husen, T. (Ed.). (1967). *International study of achievement in mathematics: A comparison of twelve countries* (Vol. 2, p. 23). New York: Wiley.

Jacobson, W.J., & Doran, R.L. (1985, February). The second international science study: U.S. results. *Phi Delta Kappan*, p. 414.

Marsh, P., & Gartner, R. (1963). *Federal aid to science education: Two programs* (p. 41). Syracuse, NY: Syracuse University Press.

McDonnell, L. and McLaughlin, M.N. with the assistance of Cox, M., Elmor, R.W., Myers, C., and Zellman, G. (1980). *Program consolidation and the state role in ESEA Title IV*. Santa Monica, CA: Rand Corp.

Minnesota Research and Evaluation Center. (1983). *Images of science.* Minneapolis, MN: University of Minnesota Press.

Murnane, R.J. (1981, Fall). Interpreting the evidence on school effectiveness. *Teachers College Record*, *83*, 21-22.

National Center for Education Statistics. (1982). *Projections of education statistics to 1990-91* (Vol. 1). Washington, DC: Author.

National Center for Education Statistics. (1983). *Digest of education statistics 1983-84*. Washington, DC: Author.

National Defense Education Act of 1958, Statutes at Large, 301, 72 U.S.C. 1588.

National Education Association. (1983). *Estimates of school statistics* (p. 457). West Haven, CT: Author.

National Research Council, Office of Scientific and Engineering Personnel, (1982). *Science, engineering and humanities doctorates in the United States* (tables 1.8, 2.8). Washington, DC: National Academy Press.

Peterson, P.E. (1983). Background paper. In: *Making the grade* (chaps. 4, 5). New York: Twentieth Century Fund.

Pierce, C. (1985, June 10). Teaching without preparation: A Washington state report examines out of field assignments, *Education Times*, p. 5.

Rumberger, R.W. (1984). *Is there really a shortage of mathematics and science teachers? A review of the evidence.* (Report No. 84-A26). Stanford, CA: Institute for Research on Educational Finance and Governance, Stanford University.

Sufrin, S. (1963). *Administering the National Defense Education Act* (p. 41). Syracuse, NY: Syracuse University Press.

Surprises and uncertainties: Annual report on the economic status of the profession, 1981-82. (1982, July-August). *Academe*, p. 9.

Travers, K.J., & McKaight, C.C. (1985, February). Mathematics achievement in U.S. schools: Preliminary findings from second IEA study. *Phi Delta Kappan*, p. 417.

U.S. Bureau of the Census. (1980). *Population estimates and projection* (Current Population Reports, Series P-25). Washington, DC: U.S. Government Printing Office.

U.S. House of Representatives. (1983). *National Engineering and Science Personnel Act of 1983*. (House Report 98-6). Washington, DC: U.S. Government Printing Office.

U.S. Office of Education. (1959). *Guide to the National Defense Education Act* (p. 9). Washington, DC: U.S. Government Printing Office.

U.S. Office of Education. (1963). *Report on the National Defense Education Act, fiscal years 1961 and 1962*. Washington, DC: U.S. Government Printing Office.

U.S. Office of Education. (1969). *NDEA Title III, fiscal years 1959-1967: A management view* (p. 17). Washington, DC: U.S. Government Printing Office.

U.S. Office of Planning, Budgeting and Evaluation. (1978). *Annual report on programs administered by the U.S. Office of Education, fiscal year 1977*. Washington, DC: U.S. Government Printing Office.

U.S. Senate. (1983). *Education for Economic Security Act*. (Senate Report 98-151). Washington, DC: U.S. Government Printing Office.

EXCELLENCE AND EQUALITY: THE CONTRADICTION IN SCIENCE TEACHING IN AMERICA

Edward B. Harvey
Ontario Institute for Studies in Education and University of Toronto
and
Lorna R. Marsden
University of Toronto

Introduction

The numerous reports on the quality of school teaching in America have spurred a great debate.[1] *A Nation at Risk*, reports from influential groups, and the responses to those reports debate the need to modernize America's school system, with a special concern for science education and teaching. In his review and critique of these reports, Paul E. Peterson of the Brookings Institution comments, "With some exceptions, the studies do not address the most difficult conceptual and political issues" (Peterson, 1985, p. 127).

We agree with Peterson's criticisms of the reports. With regard to proposals to improve science education, two topics need to be addressed in conceptual terms.

The first concerns the characteristics of the internal labor market of teaching and the probable consequences of increased pay, merit pay, intensification of the academic education process in schools, and other proposed actions to improve quality that rearrange the internal dynamics of the occupation. We analyze the pressures that have led to the contemporary form of teaching, and then consider whether it is feas-

[1]The reports referred to in this chapter are: *A Nation at Risk* (National Commission on Excellence in Education, 1983); *The Nation Responds* (Education Commission of the States, 1984); *Educating Americans for the 21st Century* (National Science Board Commission on Precollege Education in Mathematics, Science, and Technology, 1983); and *Making the Grade* (Twentieth Century Fund Task Force on Federal Elementary and Secondary Education Policy, 1983).(See References for full citation.) In the text, we identify them as follows: *A Nation at Risk* and *The Nation Responds* are identified by title, and the National Science Board Commission report is used to identify *Educating Americans for the 21st Century*. In addition, the critique of these reports is a key document, referred to here as the Peterson analysis (Peterson, 1985).

ible to separate science teachers from other teachers. We think it is—but probably at major cost. We believe further that this approach fosters elitism and reduces equality.

The second topic is the major contradiction in the objectives bestowed on the public school system in U.S. society. That contradiction—between the production of "excellence" and the mass production of social mobility and open, equal opportunity for all Americans—is at the heart of the debate about science education. To quote from the National Science Board Commission report: "By 1995, the Nation must provide, for all its youth, a level of mathematics, science and technology education that is the finest in the world, without sacrificing the American birthright of personal choice, equity and opportunity" (National Science Board Commission on Precollege Education in Mathematics, Science, and Technology, 1983, p. v). Such objectives beg the question not only of how so much is to be achieved, as Peterson points out, but of the dynamics of a class-divided society that wants a technocratic elite. The Commission says that "excellence and elitism are not synonymous," and then buries its head in the sand.

Organization of the Chapter

This chapter is divided into two major sections corresponding to the two major topics outlined above. The first section describes three sociological models of professions. The debate over whether or not school teaching is a "profession" relates closely to the history and culture of teaching in the United States (the debate is different in other societies). After outlining the three models, we draw some conclusions about the usefulness of the debate today especially as a means of resolving the current urge for the reform of science education.

The second section, "The Debates on Science Education," focuses more specifically on the internal debates about the objectives and the methods of science education. We find that the contradiction analyzed in the first section that bedevils the school system as a whole is at the heart of the problem of science education.

A third section looks to future means of untying the tangled knot of current debates on U.S. science education.

The Debates on Teaching as a Profession

Science teachers are the focus of attention in several major reports because of the fear that America may be falling behind technologically and in world competition. However, science teachers, at present, are not professionally, organizationally, or socially distinct from their teaching colleagues. To understand their situation, one must examine the general situation of all secondary school teachers.

Is teaching a profession? This question has dominated the educational literature in the United States since the late 19th century and exemplifies an important concept in U.S. culture. It is an important question because of the community's perception of the word "profession." In the United States the term evokes high status for the occupational group so labeled and high esteem for the individual who approaches work "professionally" no matter what the occupation. The idea of the combination of service to the community and success in living standards is summarized by the word "profession." In short, being or becoming a professional is inextricably linked to the American ideals of democracy and social mobility which explains why teachers and other groups have been, and still are, preoccupied with questions of professional status.

Three models dominate the sociological literature on the professions in America. Until recently the most prevalent has been the model of professionalization or the trait model, which we describe first. The second model is concerned with the power of the occupation relative to other occupations. The third, more recent, model is of a social historical or cultural nature. It examines the complex nature of U.S. culture and society and the role played by various occupational groups within it. As we shall see, there is no unequivocal acceptance of teaching as a profession and the last two models render the question irrelevant from an analytical perspective. It remains a question in the minds of many practitioners and Americans, however, and is often raised in the current debate.

The Professionalization Model

From the earliest days of American schooling, analysts have been concerned with the status of teachers in relation to other occupations. Since the turn of the century there have been sociological studies of various groups in relation to those occupations widely regarded as "true" professions—medicine, law, theology, architecture (the list changes)—and of the process by which occupations become "true" professions. Nurses, pharmacists, and teachers have been among those who are in the process of "professionalizing" (Wilensky, 1964).

Studies over the years have identified the traits that characterize "true" professions. The list of traits varies by author and by year, but in general the following traits are included: an abstract body of theory or esoteric knowledge upon which the practice of the occupation is based; a long period of training through which this knowledge is acquired in a university; an ideal of service to the community takes precedence over material or economic gain; exercise of control, devolved upon the occupational association by law, over who may enter the occupation; exercise of control over certification and practicing standards; and collegial control and discipline that enforces the code of ethics, disciplines errant practitioners, and ensures considerable autonomy for the occupational group and the individual practitioner.

While many have asserted the professional status of teaching (Lieberman, 1956; Musgrave, 1965) some doubt that teachers meet the characteristics of a true profession and call the group "semi-professional." The semi-professionals are described by Etzioni (1969) as lying on a scale of professionalism but distinguished from professions by more bureaucratization of their employing organizations; by a shorter period of training; a less recognized status in the community; less specialized knowledge; and less established right to privileged communication (Leggat, 1970). Leggat prefers the description "bureaucratic professions."

U.S. analysts also have pointed to other traits that separate teachers from the true professionals. In *Education as a Profession* (1956), Lieberman said. "The predominance of women. . .must be regarded as one of the two or three more important obstacles to the professionalization of education" (p. 242). Although Lieberman acknowledged his prejudice, he asserted, "Education will not become a leading profession unless either the proportion of men to women is drastically increased or there occurs a cultural revolution concerning the role of women in American society" (p. 242). Other characteristics of teachers such as their own social class origins in comparison with the "true" professionals are also held to reduce their status. A greater proportion of teachers are from lower middle class and working class families than is true of doctors or lawyers.

At best, teaching is not a full-fledged example of the professionalization model because of the status that characterizes its practitioners, its organizational locus in the bureaucratic organization, and its standing in the eyes of the community. Science teachers are no different from other teachers in this model.

The literature on the subject until the late 1960s shows a distinct ambivalence about the professional status of teaching. On one hand, the authority of the teacher was seen to arise from professional autonomy, the moral character of teaching, and the relationship between education and democratic society (Becker, 1953; Corwin, 1965, Ch. 4). On the other hand, the characteristics of teachers, the bureaucratization of the school system ("Is the NEA Controlled by Administrators?" is one of Lieberman's section headings), and the unionization of teachers are seen by some as deterrents to "full" professional status (Baron and Tropp, 1961, p. 552).

This ambivalence is exemplified in the descriptions of the roles of the National Education Association (NEA) and the American Federation of Teachers (AFT). The NEA is the professional association comparable with the American Medical Association and the American Bar Association in its role of protecting the autonomy and ethics of practitioners, assessing training institutions, and resolving disputes within the occupation. The AFT and other unions protect the rights of teachers and are concerned largely with teacher welfare issues.

At present, however, the union movement is strongly advocating more "professionalism" among teachers including a code of ethics, more autonomy for practitioners, a stronger method of selection and maintenance of standards. In recent remarks, Albert Shanker, President of AFT, stated that if teachers are to achieve professionalism, they have to "...develop new processes, new institutions, new procedures which will bring us what teachers want in addition to what we get from collective bargaining: status, dignity, a voice in professional matters, the compensation of a professional" (Shanker, 1985, pp.5-6).

This call for adherence to the characteristics of the "true" professions can be seen as a straightforward attempt to improve the social and economic status of teachers. Evidence to support this is found in the constant comparisons and references to doctors and lawyers in Shanker's speeches: "In fields like medicine, if one experiences a shortage of doctors, you do not find states or hospitals giving anyone a substitute emergency medical license to go out and practice" (Shanker, 1985a).

Equally feasible, however, is the interpretation of this argument in terms of our second model of professions which concerns their power and control over their work. When demand for teachers was high, professionalizing seemed appropriate. However, as the demand for teachers slackened, the debate about professionalizing began to take another form. Teachers became more interested in controlling their working conditions, job security, pay, and equal opportunity thus making collective bargaining more crucial.

The Model of Power and Control Distinguishing Professions

In the countless discussions of professional traits and teaching as a profession, the issues of autonomy and control are always important. The moral authority of the teacher in the classroom and the right of the teacher to determine the preparation of classroom materials are important issues in teacher training and professional discussions. However, it has always been acknowledged that these powers and autonomy exist within narrow limits. The debate about the power of administrators has been present from the beginning.

Increasingly, therefore, analyses of the occupation turned to the relationship between the individual in the classroom and the organization of the occupation as sociologists began to examine issues of power and control.

The United States, in particular, became a nation of sophisticated consumers of professional services. Who would determine what type of medical, legal, educational, or other professional services we would receive and how we received it? The power or control over these decisions coincided with the increased desire to enter the professional occupations among people from a much wider range of social and economic backgrounds. In teaching, several changes occurred. There was increasing labor force participation among women, especially married women. This increased the pressure on teaching because, at the same time, the growth in school enrollment was declining. The civil rights issue of the 1960s caused more women and minorities to resist being squeezed out of the educational system as teachers or administrators. Finally, because the rate of college attendance had increased greatly the potential supply of teachers was greater than ever (Freedman, 1976, p. 95; Twentieth Century Fund Task Force on Federal Elementary and Secondary Education Policy, 1983).

Thus, the union began to be more important than the professional association in protecting those who were already employed. As Freedman analyzes the situation, American workers are best off in the labor market if they have shelters both of a professional kind (e.g., licensing) and of a union kind.

By the 1970s teachers had long been professionally protected by their association but fewer had been members of unions. Union membership now rose, so that teachers became better able than many occupational groups to protect their jobs and bargain for salary increases in the downturn years in the economy. Such labor market factors are important for explaining both the occupational concern about professionalizing and the shift from one model of explanation to another.

While Lieberman in 1956 could assert that the dominance of women was a problem and suggest methods for attracting men to teaching, Oppenheimer (1970) reported both how elementary teaching became feminized originally (women replaced men who found better jobs elsewhere) and why by 1960 men were flocking into elementary teaching. Many have shown that teaching was a route to upward mobility for men from lower-middle- and working-class backgrounds. It was a route to school administration and the earnings were quite high relative to blue collar and clerical jobs. As the post-1960s labor market trends turned to the struggle to maintain jobs and enter administrative jobs, married women permanently in the paid labor force were in severe competition with upwardly mobile men who saw classroom teaching as a route to advancement. The question of professionalization took on different emphases.

The trait, or professionalizing, model was unable to explain what had become the key concerns of the occupation during the 1960s and 1970s. Job security, advancement, and entry became issues largely due to the changing demographic and labor market conditions. But the other powerful change in the 20th century—bureaucratization—was also a pressure on all professionals (Corwin, 1965, chap. 2; Cotgrove & Box, 1970).[2] Increasingly, members of occupations trained in the manner of professionals found that their jobs were set in terms of bureaucratic goals in large organizations and that their pay was salaried rather than fee for service. The rise of private corporate and government bureaucracies increasingly changed labor market conditions.

In the United States, Eliot Freidson began to elaborate his model of the professions as agents of social control over various forms of social deviance (Freidson, 1970a, 1970b). He emphasized in his study of the medical occupation the social development, organization, and maintenance of autonomy for the practitioners. He showed how doctors created their own social reality and got patients to accept this medical modeling of their situation. Since doctors are always the favorite touchstone of the study of professions, Freidson's ideas generalized to many occupations. In education, the idea was not new (Becker, 1952; Collins, 1971) and led eventually to the Marxian critique of Bowles and Gintis, *Schooling in Capitalist America* (1976), in which the education system is viewed as working in the interests of capital.

The focus on professionals and control was widely accepted. Johnson (1972) had rejected the "trait" model and offered analyses of three forms of occupational control which characterize the relationship between the client and the practitioner. Who controls that relationship is important because it is in that exchange that the expertise of the professional (which is what distinguishes them from other types of workers) is exercised. This is the crucial concern of teachers, as well as doctors and lawyers. Does the teacher decide how the student can best learn or does the principal, school board, or department of education decide?

The first, collegial, model exists where the practitioner tells the client the services to be received and how they are to be received. This is the closest to Freidson's description of the autonomous reality created by the fee-for-service physician in America.

[2]Bureaucracy, considered by many to be the most powerful form of controlling work and organizations, depends upon a hierarchical division of labor, the anonymity of the office holder, the keeping of detailed records of decisions and processes and the uniform application of those rules to all. In bureaucracy, there is no individual decision-making because each officer follows the rules and the law and the precedents. Each officer can be replaced by anyone else trained to that job or office. Bureaucracy is efficient but very impersonal. Professionalism is highly personal because judgments lie with the individual practitioner only guided by the rules. The tension between the power of bureaucracy and all other forms of decision-making is the great dynamic of the 20th century.

The second, patronage, model exists where the client tells the practitioner what is wanted and how it is to be received. This is the situation of most architects in the modern world whose clients are powerful corporations, or other "professionals" who work for a bureaucracy or corporation.

The third, mediative, model exists where a third party advises clients of the services available and advises the practitioner what services to provide. This third model describes the situation of doctors in a system of universal health care and describes the situation of most public school teachers for whom the curriculum is prescribed and for parents who are told by the board of education what their child may expect.

In his analysis of teaching as a profession, Leggat (1970) remarked that the profession question is probably of more interest to the historian than to the sociologist. Throughout the 1970s, and with increasing focus, sociologists have looked for an historical framework or method for analyzing occupational groups and social classes. What was happening in the labor market and in the economy could not be explained through existing sociological models. How did doctors gain so much control and prestige in American society? The model of power and autonomy continues to be of considerable interest in the analysis of professions, but a new model has developed.

The Cultural Analysis Model

Just as the power model has its roots in the earliest concerns with autonomy and control in the study of professional occupations, so is concern with the cultural setting of the school system found in the early descriptions of occupations in America. This third model relates the values and changes in American culture and society to the rise and fall of occupational groups, including professions. Burton Bledstein's study, *The Culture of Professionalism: The Middle Class and the Development of Higher Education in America* (1976), best exemplifies this school of thought.

In this study, Bledstein traced the social and historical origins of the American middle class, a class different from the European bourgeoisie and committed to both serving society and improving its own standard of living. He described the creation of this dominant class as a process of social mobility rooted in the public educational system, open to all Americans, and capped by a university system conferring professional status on many occupations. This model of professions explains why the various traits isolated in the professionalizing model exist the way they do in America—why, for example, an extended period of study in a university is crucial to the social status of a profession when it has no rational basis in training.[3]

Social historians applying this analysis to teaching argue that teachers lost occupational control over decisions crucial to teacher–pupil relationships by the end of the 1890s in the United States as schooling became bureaucratized. School superintendents had seized control of the organizations and therefore of the occupation and were able to determine the work of classroom teachers (Larson, 1977).

In terms of the internal organization and structure of teaching, therefore, the most recent analyses enable us to comprehend one side of the teaching dilemma. Just as scientists working in big corporations struggle with division of loyalty between corporate bureaucracy and scientific objectives, so one can appreciate that the science teacher is caught between solidarity with other teachers and interest in the work of chemists, physicists, and mathematicians working elsewhere. The internal labor market struggle of the past decade forced science teachers to demonstrate their loyalty to their profession rather than to their discipline. Thus, they have become "locals" rather than "cosmopolitans," "teachers" rather than "scientists."

This internal dynamic has been reinforced by the other side of the teachers' dilemma, the desire for social mobility. This is the other promise of professionalism in America. Not only are science teachers less likely to keep up with their field or to have been top science students to start with, but the conditions of teaching (e.g., curtailment of travel funds and continuing education opportunities) have reinforced the inward-looking career structure. The route to advancement for the science teacher is through becoming a principal, not becoming a top scientist. The choice between excellence and equality is best negotiated for science teachers by climbing the ladder of the school system.

Although Turner (1961) published a perceptive analysis of this dilemma, none of the current reports directly faces this contradiction that plagues educational reform in America. In "Modes of Social Ascent Through Education," Turner described in rich detail how "the accepted mode of upward mobility shapes the school system directly and indirectly through its effects on the values that implement social control" (p. 121). Turner outlined two educational systems, the sponsored system of the British and the contest system of the Americans. Under the sponsored system, the focus is on careful selection of talent at an early age and the training of those chosen to occupy the elite positions in many domains, including science. The primary problem of this system is the proper method of talent selection. The system "cools

[3]For the medical profession, this model has been expanded in Paul Staff's 1982 Pulitzer Prize winning *The Social Transformation of American Medicine*, in which the forces of American middle class dominance, of bureaucratization of the public health system, and now of the private corporation, are described in an historical context.

out" those not chosen by giving them a "realistic" view of themselves in the social system and inducing strong loyalty to the system. The contest or American system, on the other hand, focuses on an endless series of competitions open to all, and those who fail may try again. Individuals are expected to get ahead by themselves. The system encourages those who don't succeed by providing a future orientation (next time I'll succeed), and encourages a camaraderie with the elite and an ideology of equality.

Consider Turner's systems in relation to science teachers. Although recent reports show that science teachers are a declining proportion of new entrants to teaching, that they have often fallen behind in their knowledge of new developments in science, and that they have little access to continuing education, the authors of the reports appear to believe that these are not significant barriers to a good science and math education for everyone (National Science Board Commission of Precollege Education in Mathematics, Science, and Technology, 1983, p.xi). Such sentiments expressed in the Science Board Commission report coincide well with Turner's description of the American ideology. Further, the stress in the reports on the avoidance of elites is consistent with Turner's depiction of the contest model. Yet there is now, and always has been, evidence that American society is highly differentiated by education, occupation, and income and that upper-class Americans provide a better education for their children than most Americans can afford. The liberal pressure to open opportunity, to help the disadvantaged, to provide remedial education for teachers, and to achieve equality means that resources cannot be too concentrated on excellence. The National Science Board Commission recommends expansion of model schools and exemplary programs in every community (1983, pp.23-25). The model schools argument is, as Peterson points out, a tiny aspect of the general problem ofbetter math and science education.

We do not argue that the American objectives are wrong. We argue that in the reports the central contradiction between excellence in mathematics and science and the "American birthright" has not been faced either in recommendations to improve teaching or in the analysis of teachers as a "professional" group.

Through our description of three different models of the professions in America we have focused on three matters central to the current debate. First, there is no such creature as a "profession" in any fixed way but only as an occupational group in relationship to other groups. Second, changing demographic, social, and economic circumstances affect not only the demands on the education system but the way in which teachers argue for their occupational group. Third, the central dilemma of teachers is the central contradiction of American culture—the unresolved desire to be both equal and excellent, to be open to everyone, and to still produce the best.

Are teachers professionals? We conclude that it doesn't really matter. They are a strongly sheltered, powerful group rendering an essential service. The current priority of the teachers' unions to make teaching more professional is more of a labor market strategy and desire for increased power than a useful means of reforming education for the 21st century and the post-industrial age.

The Debates on Science Education

Having described science teachers as a group caught in the contradiction between excellence and equality and having argued that the organizational power and status of teachers are not the key to achieving those contradictory goals, we now turn to the similar contradictions in the debates on science education in contemporary America.

A Nation at Risk, and the accompanying reports and the resulting comments reflect the intense concern over American interests in science and technology. They also show the narrow scope of the debate so far. Some reports are written in dramatic language, evoking feelings of nationalism and international competitiveness. Their recommendations seem to be a call to national unity and mobilization rather than to specify strategies for better math and science education.

The Nation Responds takes a different approach, emphasizing the national will, the funding commitments, and the state-by-state efforts at reform. There is a disjunction here. *A Nation at Risk* calls for better citizens to preserve democracy and world leadership. *The Nation Responds* calls for better communicators, scientists, and technologists to make America more competitive in a world where, as the report says, there is a "redistribution of trained capability" throughout the globe. However, as its critics have pointed out, organizational innovation does not characterize *The Nation Responds* any more than it did the original report.

The problem is evidenced in the debate in science education (Good, Herron, Lawson, & Renner, 1985; Watson, 1983; Yager, 1980, 1983, 1985). There is consensus in problem definition—that a lack of clarity about the objectives and goals of science education exists.

Yager proposes that the interrelationships between science and society comprise the domain of the science curriculum. He argues that focusing science teaching and science education research on the science/society interface provides a rationale and a coherence that is lacking in curricula devoted to the knowledge products of science (Yager, 1985). Moreover, Yager argues that the definition accommodates the dynamics of a changing science and its impact on society as well as a changing society and its impact on science. Viewing the discipline as a science/society interface places special emphasis on the relevance of science in today's society, giving meaning to the concept of the "new basics" by focusing attention on remedies to declining American competitiveness in traditional industrial sectors (e.g., auto and steel) and in high technology sectors.

Critics of Yager's view suggest that a focus on the science/society interface reduces science education to a social science (Good, Herron, Lawson, & Renner, 1985; Watson 1983). Why this is necessarily bad is not explicitly discussed. While education research and theory may be appropriately viewed as part of the domain of the social sciences, these critics feel that these concerns are naturally subordinated to the work of "real" scientists. That is, they express the major concern of science education researchers as identifying those factors that help people learn science, "science as defined by scientists, not by sociologically and/or politically oriented observers" (Good et al., 1985, p. 140).

These opposing views highlight two dilemmas. One is in evaluating the professional status of science education, the other is in broadening the debate about defining the goals of science to examine the institutional relationships.

For the first, Yager believes that there is a distinct body of knowledge that encompasses aspects of the social sciences and the sciences that defines the content domain for science education. This is labeled a "soft" definition of science by critics because it permits "inordinate" influence by nonscientists on science curriculum development and a loss of technical excellence. These critics suggest that the discipline defined by Yager does not yet exist as a definable body of knowledge (Watson, 1983). The implication is that "real" or "pure" science needs to be taught in science classes, not as something that integrates the natural and social sciences.

These opposing views encompass a second dilemma, that of examining institutional relationships. Yager (1985) replies to his critics that by focusing principally on the scientist's agenda, the education system runs the risk of reinforcing an "elitist" view of science education. Elitism leads to a loss of relevance to students in an all-encompassing education system. Further, Yager argues that if the science/society school is not adopted, educators may never discover why American students are falling behind in their grasp of critical scientific knowledge.

Neither group seems to consider excellence in scientific *and* social endeavors as a reasonable criterion for defining the content for science education. They do not, in part, because they do not critically examine the organization of the teaching occupation or the school system.

This debate between advocates of science/society and pure science approaches reflects the general American debate about excellence and opportunity. This is not to say that only elites produce excellence but that the recommendations of the various reports—most particularly the National Science Board Commission and *A Nation at Risk*—

essentially suggest that science teaching should return to "basics" taught by teachers who have been specially selected by their training, salaries, and working conditions—that is, an elite group of math and science teachers. In short, while eschewing elitism, these reports seem to suggest that the creation of an elite teaching corps is the only way to achieve excellence. The creation of a teaching elite, however, by no means implies that every American school child will have a good education in mathematics and science throughout the school years (Yeakey & Johnston, 1985).

This debate is inadequate because it fails to articulate the specific issues: If the United States is to remain competitive in the world, is the main requirement a larger cadre of excellent scientists identifying and drawing on all the available student talent, or is the main requirement an entire work force which has well-developed skills and knowledge in mathematics, science, and technology? Either way leads to reforms in the current formulation of science education but the task facing the teacher is quite different in each case. Is the teacher to be so well integrated with his or her field that teaching only very good students will be rewarding, or is the teacher to address himself or herself to ensuring that every student knows as much as possible? Will the school system stream students at an early age to produce more science/math students, or will it maintain its current function of general education for all?

To answer these questions, we must address the ideology of American democracy in the modern world of distributed resources, technology, and human brain power. If the ideal of social mobility of every American conflicts with the ability of the American economy to be internationally competitive, which gets priority?

Americans must debate education (particularly science education) in terms of the basic values concerning social mobility and the rights of citizens because a fundamental shift is taking place in industrial economies. There is now overwhelming evidence that the industrial era is being replaced by a post-industrial or information age (Reich, 1983).

Reich characterizes this new world as one in which each worker puts more brain power, more decision-making capacity, and more flexibility into the job. It is a world in which supervisors and managers must work with production workers in a new collegial fashion. Mass production is dying out, although machine-controlled processes may be increasing. The need for each person in the economy to be literate, numerate, analytical, and confident is recognized in such popular essays as *In Search of Excellence* (Peters, 1982). In industrial America the ideas and values about social mobility remain strong, but this mobility has been evidenced in consumerism rather than in production. It is the demands of the labor market that are putting the nation at risk, as the reports imply.

The debate then is not about the science/society interface or education in "real" science but about the links among (a) the labor market, (b) the skills and attitudes of workers entering that market, and (c) the contribution of science education. The educational system is only one way of institutionalizing values about social mobility and demands of the economy. The problem the educational system must face is that values about social mobility have not changed very much while the labor market has changed a great deal and is expected to change even more and in ill-understood ways.

A second issue that is important for defining the scope and domain of a science education discipline relates to direct measures of the separability of science education from the education system as a whole. This issue is being discussed in terms of changes in the status of science education in state departments of education (Dowling & Yager, 1983) and in graduate entry for science education (Yager, Bybee, Gallagher & Renner, 1982). Dowling and Yager (1983) collected current and retrospective data from state science supervisors in an attempt to identify changes in position characteristics over time. They appear to have isolated measures of a declining professional status between 1965 and 1980: a reduction in specialized scientific work in favor of a greater responsibility in general education; a reduction in program and curriculum development work in favor of greater supervisory, administrative, and regulatory work; and a reduction in freedom to establish a work schedule or to travel in-state and out-of-state in favor of a more rigid work schedule (assigned by others) and severe restrictions in travel. The study does not compare this apparent decline in professional status for science educators with state supervisors in other disciplines. Therefore, we do not know the extent to which these apparent trends are unique to science educators, nor do we know whether there have been compensatory increases at the local level.

This analysis suggests that the U.S. education system has been undergoing extensive change in the past 20 years. These changes may well be basic to the inquiry into science education as a discipline. However, this remains only a hypothesis because the nature of these changes has not been properly examined either by *A Nation at Risk* or by science educators. Thus, the debate centers on unverifiable propositions—that science education is (or is not) the science/society interface—or status measures (e.g., in-state departments of education or graduate jcenters of science education) that may or may not have validity. In the absence of explicit debate over these issues, the definition of science education tends to emerge from unexamined assumptions in the reports. Without examining these assumptions and reexamining national institutional arrangements, we cannot tell how best to develop science curricula and teaching when governance and financing are primarily local and state responsibilities. Nor can we suggest how these issues can be reconciled with calls for an increased emphasis on national standards in testing. (We accept the doubts cast by Peterson and other critics on the evidence of a decline in education [Peterson, 1985, pp. 128-131]).

In the discussion in the first section, we showed how teachers have tried to deal with the desire for upward social mobility by increasingly sheltering their occupation through collective bargaining and more occupational control (Freedman, 1976). We also indicated that teachers' salaries, although low compared with other occupational groups with the same educational level, have improved relative to the past (before the most recent teacher surplus coincided with the recession of the 1980s). Thus, teaching has continued to attract Americans from a wide range of social class backgrounds by remaining a route to improved social standing.

One cannot assume that teachers of chemistry have much in common with industrial chemists or chemistry professors. Their class origins are likely to have been different. Their occupational associations have separated rather than united them. Their employers have rewarded them as teachers not as scientists and thus commanded their loyalty. Therefore, when it is suggested that they will benefit from travel to scientific meetings, it cannot be assumed that they will be anxious to go. Not only has there been no inducement for them to keep up with scientific advances, there has been positive organizational and collegial reinforcement for not doing so. These divisions and strains have been reinforced, institutionalized, and sanctioned by state and local jurisdictions, and until recently by unions and professional associations. It is striking that in the studies of science and scientists, science teaching is mentioned only in relation to postsecondary education (cf., Cotgrove & Box, 1970; Krohn, 1971). School teachers of science are not analyzed as scientists.

Professionalization as a social movement on the part of occupational groups has reinforced the boundaries around "teachers" but has not distinguished science teachers, still less physics teachers, math teachers, or biology teachers.

A Nation at Risk has taken up the issue of the market for science educators. It points to the shortfall between teacher supply and the demand for science teachers who possess a minimum level of qualification. Williams (1983) was able to demonstrate for North Carolina that part of the shortage can be viewed as a solvable problem in human resource allocation. For example, his analysis of the science teacher shortage in North Carolina showed that many of teachers who lack sciencequalifications are teaching science courses (as expected) and many teachers who possess science qualifications are teaching in non-science disciplines or holding nonteaching jobs within the jschool system (which was not expected, but should have been if there had been an analysis of the union power in that occupation). This leads to such short-term remedies as retraining science teachers in subject areas for which there is high demand (e.g., physical sciences or mathematics). There are many problems associated with retraining of science teachers (Williams, 1983).

In another experiment, a Canadian province tried to persuade sciencc teachers to upgrade their science skills by offering them a Master's degree for part-time study in physics and math; however, almost no teachers who were interested in the program qualified for entry. In other words, the knowledge now required for a bachelor's degree is well beyond that already achieved by most in the teaching force so that upgrading essentially means earning a bachelor's degree again. Further, most teachers of physics and mathematics only minored in those subjects as undergraduates. Thus, even when they first entered science teaching, they were less well equipped than other scientists. Presumably those who could get jobs in industry and government did so, and those who couldn't ended up teaching.

Serious shortages of qualified mathematics, science, and technology teachers nationwide have been acknowledged both by *A Nation at Risk* and by the National Science Board Commission (1983). These shortages are worst in mathematics, physics, and chemistry (Akin, 1983) and are occurring despite an overall surplus of teachers in the country (National Commission on Excellence in Education, 1983, p. 23). Moreover, these shortages have been identified at different stages of the staffing process. In 1982, 42 states reported problems in recruiting secondary school math, physics, and chemistry teachers (Howe & Gerlovich, 1982). Shymansky and Aldridge (1982) found a decline between 1971 and 1980 in numbers of students enrolled in mathematics and science practice teaching, that only half of these student teachers ended up in teaching jobs, and that almost 25% of those currently teaching secondary school mathematics and science plan to leave in the next five years. Astin, Hemond, and Richardson (1982) report that between 1966 and 1982 the number of entering college freshmen who chose education as a major field has dropped from 22% to 4.7%.

The suggested remedies are too cautious. Williams (1983) recommends substitution and reallocation to use the available qualified people where they are most needed. The upgrading of entry requirements for science education positions by codifying minimum certification standards (in effect, restricting supply) while at the same time increasing pay and status for entry and retention is another recommended strategy. For example, the National Science Board Commission report recommends that secondary school mathematics and science teachers have a full major in college mathematics or science, a limited number of effective education courses, and a period of practice teaching under a qualified teacher. *A Nation at Risk* calls for high educational standards, career ladders that are intended to operate as status incentives, and the liberation of teachers from non-teaching activities. Science educators (e.g., Spector, 1984) have called for a wide range of initiatives in terms of equipment and people—paraprofessionals and professional support. They suggest a decreased workload, enhanced professional image, upgrading of skills, and better means of attracting prospective science and math teachers. Either implicitly or explicitly, all these sources call for the uncoupling of science educator compensation from that of other educators and for a salary structure that reflects available market alternatives.

These remedies recognize that the institutional setting for science teaching is a problem for the reform of science education. The National Science Board Commission argues that "lockstep pay increases based on seniority and training experiences" act as barriers to "market"-based pay (National Science Board Commission on Precollege Education in Mathematics, Science, and Technology, 1983, p. 33). In addition, public spending restraint suggests that there will be winners and losers in any attempt to uncouple the salaries of science educators from others. The issues of unionization and professional associations raised above are tackled by these proposals.

Will the severing of science teachers from other teachers serve the interests of reform or improve the teaching of math and science? This is another question to be examined. Vertical integration of scientists and mathematicians in their fields of investigation and pedagogy across organization, union and professional association boundaries seems very attractive.

Debates on the Future of Science Education

We have identified three debates that are crucial to planning better science education for America: (a) the "professionalization" debate which is not meaningful; (b) the national ideology debate that is based on the twin ideas of maximum opportunity for all combined with a strong desire for world leadership; and (c) the debate between science/society and pure science education. The difficulty is not that Americans lag in the learning and teaching of science but that the school system has not adjusted to modern demands. The real issue is one of adjustment to the post-industrial age and recognition of the new realities.

The reports we have discussed emphasize the singling out of science teachers for special attention or benefits that will further "professionalize" them and improve their classroom performance. Although better pay and benefits might be acceptable, they will not break down occupational solidarity and collective bargaining because the social organization of teaching is traditionally different from other occupations in the sciences. However, we would agree that a vertical integration of scientists across organizational boundaries may be a successful approach to the realignment of the priorities of science teachers (and perhaps teachers in other areas as well, such as language teachers).

If a separation of science teachers' salaries and working conditions from the rest of the system were to challenge union boundaries, then proposals for cooperative education in science would challenge the professional association boundaries. "Science education" would be replaced by "science training," a combined project of teachers in the school system, scientists and organizations in the economy, and local educational authorities. If the objective is to get a more knowledgeable, competitive work force in place by 1995, such challenges to entrenched institutional boundaries are required. Certainly, students and their parents who are looking at work in science and technology, and in technical and related fields would not complain about suchmodern apprenticeships. Nor are such programs unknown. Every high school in Ontario has cooperative programs although not every student spends part of each day in one. More intense school experiences appeal to the college-bound elite, but for the student who finds academic learning tedious and difficult, science and technology are much more likely to be learned "on the job."

We have raised questions concerning the values and the organizational arrangements of school science in North America. Undoubtedly, considerable resistance will be encountered by established interests in any attempt to change working teachers. There is also no question that simply instituting changes or improvements that answer today's questions will not answer tomorrow's. We don't just need more scientists or students who know more science. We need a closer link among the producers and consumers of science knowledge and its use in technology and technical fields.

The Yager proposals of the science/society interface, do not present a sufficiently fundamental challenge to the existing organizational arrangements. They do not tackle the problem of the integration of science into a permanently closer connection to education in science. The science curriculum depends on the objectives of science education, and no consensus yet exists. Who should do the teaching is a question that can only be resolved within the state and local jurisdictions and with the cooperation of the National Education Association and the teachers unions. Who should study science and mathematics depends on where the future American labor markets lie. This conclusion depends on more sophisticated analyses of the future of the labor markets than has been identified in any of the reports reviewed here. Certainly little sophistication is needed to use the office computer or to produce most goods and services now on the market or contemplated for the future. What may be needed is more inquiring minds and a new independent attitude toward the importance of work and production to fuel the national campaign to international competitiveness.

References

Akin, J.N. (1983). *Teacher supply/demand: 1983*. Madison, WI: Association for School, College and University Staffing.

Anderson, R.D., Kahl, S.R., Glass, G.V., & Smith, M.L. (1983). Science education: A meta-analysis of major questions. *Journal of Research in Science Teaching, 20*, 379-385.

Astin, A.W., Hemond, M.K., and Richardson, G.T. (1982). *The American freshman: National norms for fall 1982*. Los Angeles: University of California Press.

Baron, G. & Tropp, A. (1961). Teachers in England and America. In A. H. Halsey, J. Floud, & C. A. Anderson (Eds.), *Education, economy and society* (pp. 545-558). New York: Free Press.

Becker, H.S. (1952). Social class variations in the teacher-pupil relationship. *Journal of Educational Sociology, 25*, 451-465.

Becker, H.S. (1953). The teacher in the authority system of the public school. *Journal of Educational Sociology, 27*, 128-141.

Berlant, J.L. (1975). *Profession and monopoly*. Berkeley: University of California Press.

Bledstein, B.J. (1976). *The culture of professionalism: the middle class and the development of higher education in America*. New York: Norton.

Bowles, S. & Gintis, H. (1976). *Schooling in capitalist America*. New York: Basic Books.

Collins, R. (1971). Functional and conflict theories of educational stratification. *American Sociological Review, 36*, 1002-1019.

Corwin, R.G. (1965). *A sociology of education*. New York: Appleton-Century-Crofts.

Cotgrove, S. & Box, S. (1970). *Science, industry and society*. London: Allen & Unwin.

Dowling, K. W. & Yager, R. E. (1983). Status of science education in state department of education: An initial report. *Journal of Research in Science Teaching, 20*, 771-780.

Education Commission of the States, U.S. Dept. of Education (1984). *The nation responds*. Washington, DC: Author.

Etzioni, A. (Ed.). (1969). *The semi-professions and their organization*. New York: Free Press.

Freedman, M. (1976). *Labor markets: Segments and shelters*. Montclair, NJ: Allenheld, Osmun and Co.

Freidson, E. (1970a). *Profession of medicine*. New York: Dodd, Mead.

Freidson, E. (1970b). *Professional dominance*. New York: Atherton.

Freidson, E. (1975). *Doctoring together: A study of professional social control*. New York: Elsevier.

Gallagher, J.J. & Yager, R.E. (1981). Science educators' perception of problems facing science education: A report of five surveys. *Journal of Research in Science Teaching, 18*, 505-514.

Good, R.J., Herron, D., Lawson, A.E., and Renner, J.W. (1985). The domain of science education. *Science Education 69*, 139-141.

Gross, N., Mason, W.S., & McEachern, A. W. (1958). *Explorations in role analysis, studies of the school superintendency role*. New York: Wiley.

Howe, T. & Gerlovich, J. A. (1982). *National study of the estimated supply and demand of secondary science and mathematics teachers: 1980-1982*. Ames, IA: Iowa State University Press.

Johnson, T.J. (1972). *Professions and power*. London: Macmillan.

Krohn, R.G. (1971). *The social shaping of scien[illegible] institutions, ideology and careers in science*. Westport, CT: Greenwood.

Larson, M.S. (1977). *The rise of professionalism*. Berkeley: University of California Press.

Leggatt, T. (1970). Teaching as a profession. In J.A. Jackso[illegible], [illegible]d.) *Professions and professionalization* (pp. 153-178). Cambridge, [illegible]ngland: Cambridge University Press.

Lieberman, M. (1956). *Education as a profession*. Englewood Cliffs, NJ: Prentice-Hall.

Musgrave, P.W. (1965). *The sociology of education*. London: Methuen.

National Commission on Excellence in Education. (1983).*A nation at risk: The imperative for educational reform.* Washington, DC: Author.

National Science Board Commission on Precollege Education in Mathematics, Science and Technology. (1983). *Educating Americans for the 21st century: A plan of action for improving mathematics, science and technology education for all American elementary and secondary students so that their achievement is the best in the world by 1995.* Washington, DC: Author.

Oppenheimer, V.K. (1970). *The female labor force in the United States* (chap. 3). Berkeley: University of California Press.

Peters, T.J. & Waterman, R.H. (1982). *In search of excellence.* New York: Harper & Row.

Peterson, P.E. (1985). Did the education commissions say anything? *Education and Urban Society, 17,* 126-144.

Reich, R.B. (1983). *The next American frontier.* New York: Penguin.

Shanker, A. (1985a, January 29). A call for professionalism. Speech to the National Press Club. Washington, DC.

Shanker, A. (1985b, April 27). The making of a profession. Speech to the Representative Assembly of the New York State United Teachers. Niagara Falls, NY.

Shymansky, J.A., & Aldridge, W.G. (1982 November). The teacher crisis in secondary school science and mathematics, *Educational Leadership*, 61-62.

Spector, B.S. (1984). Incentives to increase the number of qualified science teachers in precollege institutions, *Science Education, 68,* 153-162.

Starr, P. (1982). *The social transformation of American medicine.* New York: Basic Books.

Turner, R. E. (1961). Modes of social ascent through education: Contest and sponsored mobility. In A. H. Halsey, J. Floud, C. A. Anderson, (Eds.), *Education, economy and society.* (pp. 121-139). New York: Free Press.

Twentieth Century Fund Task Force on Federal Elementary and Secondary Education Policy. 1983). *Making the grade.* New York: Twentieth Century Fund.

Watson, F.G. (1983). Science education: A discipline? *Journal of Research in Science Teaching, 20,* 263-264.

Wilensky, H.L. (1964). The professionalization of everyone? *American Journal of Sociology, 70,* 137-158.

Williams, R.T. (1983). The science teacher shortage in North Carolina: Facts and myths, *Science Education, 67,* 479-488.

Yager, R.E. (1980). *Crisis in science education* (Technical Report 21). Iowa City, IA: University of Iowa Science Education Center.

Yager, R.E. (1983). Defining science education as a discipline. *Journal of Research in Science Teaching, 20,* 261-266.

Yager, R.E. (1985). The defense of defining science education as the science/society interface. *Science Education, 69,* 143-144.

Yager, R. E. & Penick, J. E. (1984). What students say about science teaching and science teachers. *Science Education, 68,* 144-151.

Yager, R. E., Bybee, R., Gallagher, J. J., & Renner, J. W. (1982). An analysis of the current crises in the discipline of science education. *Journal of Research in Science Teaching, 19,* 377-396.

Yeakey, C. C. & Johnston, G. S. (1985). High school reform: A critique and a broader construct of social reality. *Education and Urban Society, 17,* 157-170.

"CURRICULUM - PROOF" TEACHERS IN SCIENCE EDUCATION

Patricia Albjerg Graham and Michael Fultz
Harvard University
Graduate School of Education

Introduction

In considering the problem of science education in the United States, we focus on science teachers and how they can become more effective in the classroom—an important topic. From our perspective, excellent preparation is necessary but *by itself* is not the determining factor for teacher effectiveness in science or in any other field. Without improved working conditions for teachers, without more able and diverse persons entering the teaching ranks, and without community consensus on the academic goals of education, teacher preparation alone cannot ensure teacher effectiveness. Thus, we must simultaneously address the four issues of working conditions, recruitment, preparation, and consensus about goals for schools.

The issues that affect science teachers similarly affect other teachers. Two principal differences, however, are salient to science instruction. First, science teachers have more opportunities to leave teaching for other more lucrative positions than do most other teachers; hence, the issue of attracting and keeping able science teachers is especially critical.

Second, the science curriculum, particularly in the high school, is usually oriented to the able student, rather than the average one, but the present critique of U.S. education emphasizes the inadequacies of instruction for the average student. Science teachers, who have frequently found college-bound students to be their most stimulating ones, find the new requirement to attend to the educational needs of nonscience-oriented students especially difficult. If science teachers are to work effectively with average students, they will need to pay more attention to pedagogy and will need the full support of the local community, support that has been either ambiguous or lacking in the past.

Background

Education in America is a wondrously diverse and comprehensive enterprise. It involves nearly 40 million children and 2.5 million teachers and has prospered magnificently during this century. The widespread criticism that engulfs it today—a generational phenomenon—is more comprehensive, more informed, and more persuasive, in part, because the schools have been so successful in educating American youth. For example, in 1950 only 6% of American adults were college graduates and only 33% were high school graduates. Today 18% of American adults are college graduates and 70% are high school graduates (National Center for Education Statistics, 1983). Those better educated youth are now the critical adults, a triumph of the effectiveness of their extended educations.

For nearly a century since we have had widespread education in the United States we have had spurts of criticism at least once every generation, and those criticisms have occurred when some new group began to enter the educational system in large numbers. When the schools in general and the high schools in particular attracted only those young people who found learning congenial and whose families insisted that they attend school, the task of the schools was relatively clear. When enrollments grew to include substantial numbers of children who were not instantly drawn to what was often a relatively dull presentation of academic material and whose families' insistence on schooling was muted, the schools were forced to revise their programs to deal with these students. In many schools these students comprised the majority of those enrolled.

The response to these burgeoning enrollments has been threefold. First, educators argued that the schools should become child-centered to accommodate the varied needs and interests of the now diverse student body. Second, both educators and many lay persons agreed that the curriculum should be expanded beyond the traditional academic subjects to include a greater variety of studies that would both be more appropriate and more interesting than the rigid classical curriculum—studies that would fit the needs and interests of the child. Hence, the commitment to a child-centered curriculum meshed neatly with the conviction that traditional subject matter was unnecessary for all children. Only some—generally the minority who were college bound—needed to master the familiar classics of literature, history, mathematics, and science. Third, consensus about the purpose of schooling vanished. When schools, particularly high schools, served a narrow constituency of academically select students, agreement about what should occur in schools was relatively easy to achieve. When, however, the schools attracted large proportions of students who were not immediately drawn to conventional definitions of academic achievement, agreement about the roles the schools should play in the lives of the children became extremely difficult to achieve.[1]

[1]For a general discussion of these changes in American education as they have manifested themselves through the progressive education movement, see the references by Cremin (1961), Graham (1967), and Ravitch (1983).

The gifted, academically oriented, college-bound students found school work often challenging and demanding, and succeeded in satisfying themselves, their families, their friends, and their teachers. Typically, these were the students who studied science: chemistry, physics, advanced biology. Changes stimulated by concern for the physically, mentally, and emotionally handicapped enormously improved educational opportunities for these children who had so often been ignored. For the vast majority in the middle, the children who fell between these two groups, school was no longer expected to ensure that they master the conventional curriculum but rather adapt children's studies to meet their interests, and community agreement about what the schools should be doing for these children evaporated. For them serious study of science was nonexistent.[2]

These three concerns—child-centeredness, curriculum, and consensus—reinforced the uncertainties with which educators and the public viewed the schooling of the vast majority of children in the middle. Such uncertainty on the part of the adults did nothing to inspire the children in school to take a rigorous line with themselves on matters of academic standards. Such complicity between professional educators and lay persons concerned with education became a complicity shared with the students. Thus, schools began to serve many functions, most of which obscured the necessity and primacy of their academic responsibilities to children. Because of the ambiguity about the purposes of schooling for the great heterogenous middle of the school-aged population, and because of compelling evidence that many of them were suffering from problems stemming from financial, psychological, emotional, or social origins, many school personnel hesitated to make heavy academic demands of them, weighted as they were by other loads. In the past few years sentiment about the wisdom of such practices has shifted, and now both educators and lay persons are emphasizing greater academic learning for all children.

Reorientation to Academic Learning

The implications of these latter changes have been particularly evident in science instruction with its current dual emphasis on "science for all"—the term "scientific literacy" is frequently used to denote this purpose—and a "science 'brought to life,' science taught in a way that will make apparent its relevance to daily living and to current social issues" (Jackson, 1983). Paul Hurd argues that the fundamental issue is the "question of the place of science and technology in the wider texture of life," and he calls for "a new vision and a new educational agenda in the sciences that will focus on human concerns in the 1980s

[2]For an extended discussion of the problems of the majority in the middle, see the book by Powell, Farrar, and Cohen (1985).

and beyond." "What is sought," he asserts, "is a science program that has both scientific and cultural validity" (Hurd, 1983/1984, pp. 20–21). Some have called this reorientation to academic learning a need for excellence; others, a need for competence. Whichever term one uses, the emphasis is the same. What is less clear is how to achieve this millenium for the many.

The argument thus far has been that increased enrollments, particularly beyond the primary grades, have led to changes in the schools that have weakened the academic requirements for many students under the tacit assumption that whoever the new entrants in the schools were, they could neither perform adequately nor were they interested in doing so. Rigorous science instruction, particularly at the high school level, is a classic example of a subject intended for the small percentage of able students, not the large numbers in the middle. That these new enrollees frequently included children who were poorer, who were ethnically, religiously, and racially different from those previously enrolled reinforced the notion that they, as a group, could not and perhaps even should not be expected to achieve mastery of the traditional curriculum. Exceptions were regularly made for the rare individual in deepest poverty of whatever ethnicity, religion, or race who could "triumph over his origins" through education. The point, however, is that such triumphs were thought of as an individual, not group, phenomena. Today the issue is that of educating the group, not the rare individual for whom we do reasonably well, if not well enough. Now we have brought most children and adolescents into the schools. Our primary concern is no longer assimilating vast numbers of new entrants into the schools, although our population groups with the highest birthrates are poor and minority, with whose offspring the schools have traditionally been least successful. We now move to the most difficult question of all: how to educate well the vast majority in the middle.

Majority in the Middle

The vast majority of students—those in the middle—have had a particularly unfortunate experience in science during the past decade. The science curriculum has been influenced, especially, by: (a) the negative image science has received as a result of the Vietnam War, the popularization of health and environmental issues, and the general fear of runaway technology; (b) a back-to-basics movement in education that did not include school science among its priorities; (c) political controversies over the appropriate federal role in science education, culminating in a sharp erosion of National Science Foundation (NSF) support for projects addressing curriculum development and teacher training; and (d) the departure from the schools of many able science teachers for more lucrative and rewarding positions elsewhere.[3]

Clearly, as many here suggested, "school science has lost its favored position" (Yager, Aldridge & Penick, 1983). Not only has the so-called Golden Age of Science Education (1955-1974) ended, but its culmination has been so abrupt that "The boom of the 60s is not even a whisper in the 1980s" (Shymkansky, Kyle, & Alport, 1982).

Science education, however, was slightly ahead of other areas of precollegiate schooling in terms of mounting a comprehensive evaluation of its condition. In 1976, the same year that NSF suspended its education programs designed to improve science teaching, it funded three important research investigations on the status of school science. In 1977, *The Status of Precollege Science, Mathematics, and Social Science Education, 1955-1975* was released (Hegelson, Blosser & Howe, 1977), followed the next year by the *Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education* (Weiss, 1978) and *Case Studies in Science Education* (Stake & Easley, 1978). Also in 1978, NSF awarded a major contract to synthesize and interpret these three status studies—"Project Synthesis"—along with reports from the National Assessment of Education Progress (Harms & Yager, 1981). In 1982, the National Science Teachers Association (NSTA) launched a Search for Excellence in Science Education, an initiative using criteria developed by Project Synthesis to identify exemplary school science programs nationwide (Penick & Yager, 1983). These studies and assessments were in large measure the immediate precursors to the spate of reports on American education that began to seize public attention in the spring of 1983.[4]

Among the results of the recent analyses of science education in the schools is the conclusion that current instructional approaches do not appeal to many students. Aside from the well-publicized Scholastic Aptitude Test (SAT) score decline, not only do less than 30% of American students take three years of high school science, 85% do not take physics, 65% do not take chemistry, and 23% do not take biology; by the end of the third grade, one-half of the students say that they do not want to take science, while between the seventh and eleventh grades "science courses become less fun, more boring, less interesting, and more difficult" (Sigda, 1983, p. 625) (specifically in terms of requiring too much memorization); some 70% of 17-year-olds indicate that science classes make them feel unsuccessful, while slightly more than 50% say that these classes make them feel stupid (Bonnstetter,

[3]See, for example, Atkin and House (1981), Dow (1980), Hurd (1983/1984), Sigda (1983), and Yager (1984).

[4]See, for example, National Commission on Excellence in Education (1983), National Science Board Commission on Precollege Education in Mathematics, Science, and Technology (1983), and Twentieth Century Fund Task Force on Federal Elementary and Secondary Education Policy (1983).

Penick & Yager, 1983, p. 3). These students are, indeed, the majority in the middle.

Many of these same issues of student participation in science confronted the curriculum developers in the 1960s. Research on these curricular projects indicates that to some extent the new materials were successful in heightening interest and achievement in science for some students (Shymansky, Kyle & Alport, 1982). On the whole, however, it is becoming increasingly apparent that "science presented in the way it is known to scientists is not inherently interesting to all students" (Kyle, 1984a, p. 19). This is not to imply, however, that inquiry is being rejected as a critical thinking skill to be inculcated in the classroom, although the difficulties in doing so are now widely acknowledged. As Hurd has remarked, "For most teachers, science is still a noun, not a verb" (Hurd, cited in Jackson, 1983, p. 151).

To educate well the majority in the middle of students in both science and other subjects, we need to redirect our efforts away from creating a child-centered school and make it a teacher-centered school. Several caveats need to be added immediately: educators and the community need to agree about the curriculum for which these teachers are responsible and about the desirability that all children learn it; a teacher-centered school must be one that is not organized simply for the convenience of teachers but one that enhances their pedagogical effectiveness; school administrators must accept the critical role that teachers can play in assisting children's learning and must act to ensure that teaching schedules are not interrupted or undercut by other school activities; and teachers must accept responsibility to help children learn. If those caveats are incorporated into a teacher-centered school, we can begin to examine ways of educating well the majority in the middle.[5]

Improving Science Teaching

To shift the obligation to the teacher for ensuring that all students master the curriculum places heavy demands on that beleaguered professional. Recent reports that decry the current state of American schooling say that teachers are both the source and the solution of the dilemma. Clearly neither is true by itself. What is true, however, is that teachers can play a critical role in raising the level of educational achievement in the United States. For that to occur, however, four elements are necessary: (1) working conditions, including salaries, must change; (2) more able and diverse persons must become teachers;

[5]For a more complete discussion on the educational desirability of transforming child-centered schools into teacher-centered schools, see Graham (1984). For the historical context on the links between child-centered schools and post-World War I progressivism, see Rugg and Shumaker (1928).

(3) preparation and certification of teachers must ensure both knowledge of subjects and pedagogical competence; (4) community consensus about the necessity for all children to learn an academic curriculum must emerge.

Working Conditions and Salaries

Working conditions, including salaries, must change. The present circumstances in which secondary teachers are expected to face 125 adolescents whose minds and hormones do not inevitably gravitate to study of the Periodic Table are intolerable. Elementary teachers, who are presumed to be knowledgeable about all the "common branches," including science, and are expected to impart this knowledge and enthusiasm for more knowledge to 25 or 30 lively children, face a draining daily schedule.

The problems facing science education are perhaps most severe in the elementary grades. According to Rowe, there has been a "virtual disappearance of science in grades one through six" (Rowe, 1983, p. 136), while Stake and Easley conclude that "Although a few elementary teachers with a strong interest and understanding of science were found, the number was insufficient to suggest even half of the nation's youngsters would have a single elementary year in which their teachers would give science a substantive share of the curriculum and do a good job doing it" (Stake & Easley, p. 19:3). Survey results reported by Weiss (1978, pp. 51, 142) add to this unflattering appraisal. Fully 16% of the national sample of elementary school teachers felt they were not well qualified to teach science (compared with 3% for the teaching of reading, 4% for math, and 6% for social studies), while only 22% felt very well qualified, the lowest of the four subject areas. Weiss relates these self-reported feelings to the amount of time typically spent daily on instruction: 17 minutes in grades K–3 and 28 minutes in grades 4–6, for an average of 20 minutes daily throughout elementary schooling. These problems are exacerbated by the lack of adequate support services. Helgeson, Blosser, & Howe (1977, p. 80) report that elementary school science teachers are reassured by the availability of consultants, yet Weiss found that only 22% of the elementary school districts had a full-time science coordinator and that almost 20% of the elementary school principals felt "not well qualified" to supervise science instruction (Weiss, 1978, pp. 39, 47).

Teaching at present is exhausting physically, but even more important, psychically exhausting. Teachers who are expert in science and mathematics have left the schools at exceptionally high rates, largely because their skills, unlike those of the history or French teacher, are quite marketable outside education. In 1981, for example, five times more mathematics and science teachers resigned their positions for nonteaching jobs than for retirement (Bethel, 1984).

The most common means of teachers' adjustment to what is a fundamentally untenable situation is to concentrate their attention on those children who clearly manifest an interest in learning and—for different reasons—on those who disrupt the classroom. However, the quiet and undemanding group needs attention too, and most teachers find it nearly impossible to give them the help they need. Thus, working conditions need to be changed, to benefit both the teacher and those children who are not now receiving the instructional attention they require.

Salaries also must improve. The day is gone when discrimination against women, minorities, or members of certain ethnic groups would force those individuals into teaching, thus providing a subsidy for schooling. Today young women and minorities of both sexes who do well in school have a variety of vocational choices available to them, not just teaching. Anti-Semitism no longer forces Jews into urban school teaching as it did in the 1930s. We can rejoice in this diminished discrimination, but we must recognize the inevitable economic implications if we wish to attract able, committed persons to teaching. Data indicate that although teachers' salaries have risen gradually over the past decade, only in the past two years have these increases kept pace with the loss in the concomitant purchasing power of the dollar. The average salary for public school teachers nationwide during the 1984–1985 school year was about $23,500 (ranging from a high of $39,700 in Alaska to a low of $15,000 in Mississippi); the average starting salary for a public school teacher with a B.A. was a dismal $15,400 (Friendly, 1985; National Education Association, 1985).

Ultimately salaries and working conditions are linked because a teacher has the same responsibilities during the first year of teaching as one does in the thirtieth. Salaries are tied solely to longevity and to course completion. What is needed is a differentiation of responsibilities for teachers that allows for shifting interests over time. Such differentiation of duties can be differentially compensated, hence allowing for particularly capable teachers to be selected for extra responsibilities and extra pay. Such a practice would discourage (though not eliminate) teachers who were not selected from remaining permanently in teaching. Further, there would be financial incentives to remain in teaching, rather than leaving it for administrative positions, as is now the case.

If working conditions are to change, we need a better cooperative arrangement between the administration and the faculty than we now have in many schools. Since most of these relationships are now covered by collective bargaining agreements, adjustments will be difficult. At present, all administrators are required to have been teachers. As long as that certification requirement holds, we might add that all administrators continue to teach part-time. Such classroom duty might both remind administrators of the realities of their enterprise as well as foster the cooperation that is essential between teachers and administrators.

The fundamental issue at stake is that schools need to be organized to enhance children's learning, and the actors who can play the most immediate role in facilitating that learning are the teachers. Administrative responsibility for the institution, for the care of the children in the institution, and for the fiscal resources allocated to it are all vital and typical of the administrator's duties. Too often those tasks have seemed more gripping than the traditional one of teaching the children. The reason we have schools, after all, is to help children learn. That must be recognized as the basic premise underlying the organization. If that is so, then conditions for the persons who play the leading adult role in the drama, the teachers, need to be improved so that they can indeed fulfill their function.

Attracting More Able and Diverse Persons

More able and diverse persons must become teachers. But how can we ever expect to attract able, committed persons to teaching when the working conditions leave a great deal to be desired, when the pay is low, and when the status is diminished? Clearly both working conditions and salaries must improve as argued above, but a fundamental shift in recruitment of new teachers is also required. We must no longer rely exclusively for recruits to teaching upon the "traditional" candidate, the late adolescent, commonly female, who chooses (she thinks) a lifetime of teaching, often based on few other experiences in the world. Too often we have brought to teaching individuals whose only experiences were in schools, first as students and then as teachers. Hopefully, though not always, they have been successful themselves in school. Nonetheless, a life that has included only schooling is a narrow one. There are a few who can make an informed and wise choice for their permanent adult employment while still in their teens but not many. Too often the decision to become a teacher is made as a "fall back" choice for the unimaginative, the unadventurous, the academically weak. Such a person often fails to seek or to find employment elsewhere and, in fact, falls back into teaching. Such additions are damaging to the teaching corps and not likely to be stimulating to the students.

The shortage of traditional candidates entering math and science teaching has received considerable public attention. The data show disturbing trends: (a) between 1971 and 1980, there was a 79% decline in the number of students pursuing teaching degrees in math and a 64% decrease in science, with an 80% reduction in newly employed mathematics teachers and a 68% reduction in newly employed science teachers (in Massachusetts in 1983, for example, the 49 teacher training institutions in the state produced only two teachers certified to teach physics); (b) 42 states reported shortages of mathematics and science teachers in 1981; (c) nationwide, half of all newly employed science and math teachers employed for 1981-1982 were unqualified (hired on an "emergency" basis) with this figure rising to 84% in the Pacific states (Feistritzer, 1983; Merseth, 1985; National Science Board Commission on Precollege Education in Mathematics, Science, and Technology, 1983; Aldridge, 1982).

Surely we could benefit from some nontraditional candidates, preeminently those whose sense of status would not necessarily come from their choice of teaching and whose choice of teaching comes from a persistent and compelling interest in both the academic material to be taught and the value of having young people learn it. Some might be very young, but would seek teaching not as a permanent activity but rather as a prelude to a still-unchosen career. These young people would need to be extremely academically able with a strong social commitment. The paradigm would be the idealistic biology major who is undecided about a career in biological research, university teaching, or medicine, and who has a strong commitment to working with children.

Such young, energetic, academically able persons could infuse their fellow teachers with vitality and enthusiasm but even more they could benefit from the accumulated pedagogical expertise of the experienced teachers. Helping and teaching the novices could be a professional balm and restorative to the veterans. Three, four, or five years of teaching secondary school biology and science would give these young teachers the maturity to make the career choice that had seemed so difficult to them when they were younger. That career might now even include teaching if their experience in the schools has been rewarding. By doing so they would be providing a useful example to their own students about the difficult set of choices young people face in deciding about careers. Traditionally the upper class frequently sent their children on a "wanderjahr" upon completion of their studies; surely for many of our college graduates such a "jahr" or two might be spent not strolling through rural France (at their parents' expense) but teaching in a high school (at the public's expense). Today many private schools take advantage of this talent for their entry teaching positions. Surely the public schools might as well.

Another group of nontraditional recruits would be mid-career persons who had successfully worked in some field in which they had applied learning that they had acquired during schooling. Their ages might range from 30 to 60, and their expectations for their time in teaching might be similarly varied. In fact, one of the surprising findings of the NSTA's Search for Excellence is that many key teachers did not prepare for a classroom role during their undergraduate years (11% of the elementary and 29% of the secondary teachers) and many had worked in science-related fields before turning to education (Bonnstetter, Penick, & Yager, 1983, p. 8).

The chemical engineer who wishes to kindle an interest in science in the young rather than simply supervise chemical processes in a plant or the actuary who wishes to move from manipulation of numbers to helping students learn to manipulate numbers in a mathematics class both bring to the profession of teaching skills and experiences that substantially broaden the perspectives of classroom teaching and of the conversations in the teachers' room. Not the least of the benefits that they would bring would be their commitment to the significance of education.

Let us add that idealism in America is by no means dead, although the conventional wisdom portrays it as dormant. As many heretofore "professional" positions become ones with much less direct contact with people individually and with much more involvement with either technology or large bureaucratic organizations, more and more successful professional persons may choose to modify their career trajectory to include a period of teaching as part of their adult work life. Such an option is also enhanced by the greater prevalence of two career professional families in which both husband and wife earn regular salaries. In such cases either the husband or the wife can make a career change.

For all its disadvantages, teaching still is an intimate, significant involvement with individuals. Many professional jobs no longer are. Most of us remember one, two or, at most, three teachers who fundamentally shaped our lives. The opportunity for that kind of significance in the lives of others is denied to most people in their vocations; it is not denied to teachers, and that is a very important, though economically illusive, benefit of teaching. Fortunately some able adults, who have been successful in less intense human environments, still aspire to repay their debt by becoming one of those rare teachers who indeed profoundly and memorably assists a young person to become an informed, productive, enlightened, and concerned adult.

Recently Robert Bellah and his colleagues have completed an analysis of middle class Americans' search for meaning in their lives. Essentially their argument is that the day of viewing individuals simply in terms of their desire to get ahead is over. That explanation for American middle class motivation and behavior is both too simplistic and outdated they contend, but our categories of social analysis have not been well developed to express the more subtle yet fundamental requirements for fulfillment. They argue, "But few have found a life devoted to 'personal ambition and consumerism' satisfactory, and most are seeking in one way or another to transcend the limitations of a self-centered life"(Bellah, Madsen, Sullivan, Swidler, & Tipton, 1985, p. 290). No one would seriously suggest either that all of these persons would wish to be teachers or that all of them would become good teachers. Nevertheless, this shifting notion of fulfillment has significant implications for the pool of nontraditional, older beginning teachers. Persons who have been economically and professionally successful in an environment that stresses individual achievement may at some time wish to participate in an environment that stresses the achievement of a classroom of children. They may be developing what Daniel Yankelovich calls a new "ethic of commitment" (Yankelovich, 1981, p. 250).

Most of the examples of the shifting nature of human fulfillment are drawn from the male portion of the population and occasionally from those women who have become professionally successful during the past two decades. In many cases, these are women who a generation before might have been school teachers. Perhaps what is most striking is that we may be seeing a recognition of the validity for both sexes of some of the values traditionally associated with women in terms of service and commitment that have been undermined in some circles by the recent enthusiasm for Yuppies of both sexes. Carol Gilligan has developed this theme in her book, *In a Different Voice*, and her work has been widely cited in critiques of social commentary that assume a unitary set of values that has been associated with middle class American men (Gilligan, 1982). Should acceptance of these expanded notions of self-fulfillment become more widespread, schools could look to an expanded corps of potential teachers if the schools can recover the primacy of their obligation to serve society by educating the young.

Teacher Preparation and Certification

Preparation and certification of teachers must assure both knowledge of subjects and pedagogical competence. What is proper preparation? Research has indicated that there is no "one best system" to prepare teachers or—even more important—to work with them once they have started in the classroom to become even better teachers. Thus far, teacher training has not revealed itself as the fundamental variable explaining differences in teacher effectiveness. As Evertson and her colleagues maintain, not only is the body of research on teacher training "methodologically and theoretically anemic," they add that "Direct research on the consequences for teacher effectiveness of variations in teacher preparation programs is virtually non-existent" (Evertson, Hawley, & Zlotnik, 1984, pp. 2, 15). Studies currently undertaken by Lee Shulman and by N.L. Gage at Stanford University, by David Berliner at the University of Arizona, at the Institute for Research on Teaching at Michigan State University, and by others may not reveal much more about variations in teacher education than we now know. Nonetheless, it seems likely that the 55-year-old with a Ph.D. in chemical engineering who has been working in a large chemical company for 30 years may need somewhat different preparation for teaching adolescents chemistry than the 21-year-old undergraduate chemistry major. What those differences should be and on what they should be based (past accomplishments or future expectations) is not entirely clear.

Similarly, what the staging of education for teachers ought to be is elusive. Colleges and universities, which have provided most of the training to date, understandably follow a model of school-based instruction focused on the person planning to teach. Any attempt to provide the skills in advance of their application in a classroom is a task that will test the ingenuity of the professor and the imagination of the student teacher. Teachers with two or three years of experience are remarkably more knowledgeable about their subject matter and pedagogical strengths and weaknesses than inexperienced teachers and thus are much more apt to learn in a university setting material that will enhance their effectiveness in the classroom.

Teaching tenth grade biology for three years—and knowing that one will teach it again—puts one in an extraordinarily different frame of mind for a graduate course in genetics than one might have been in as a senior in college. Similarly, discussions about methods of questioning in a classroom are much more informative to the person who has had experience both as a recipient of student questions and as a questioner.

In short, some knowledge about both subject matter and pedagogy is necessary to get one started as a teacher, but much more is needed to make an experienced teacher an effective one.

However true it may be cognitively and developmentally that teachers should space their educations to include some periods of preparation before assuming full-time teaching jobs, while reserving significant portions of their university-based study for substantial periods of time after they have had teaching experience, it is a difficult policy to implement politically, economically, and professionally. In the end the political, economic, and professional difficulties may overwhelm the cognitive and developmental assets. Colleges and universities that prepare teachers are reluctant to let their students go for fear they will not return, a fear based firmly on evidence that indicates that the costs of being a student rise dramatically after one has become a full-salaried employee. Further, the notion that teaching is a profession in which a considerable portion of the preparation is required serially, not in advance of entry, raises questions about just when one does truly become a "professional educator."

The answer to the dilemma lies in some imaginative cooperation among: (a) school districts, which would create differentiated staffing patterns, thus providing the incentive for teachers to improve their knowledge and skills to qualify for more senior positions; (b) certification authorities, who would recognize various levels of certification beyond the present provisional and permanent ones; (c) colleges and universities, which would create both full- and part-time programs in the disciplines and in education to accommodate such study; (d) funding organizations (both governmental and non-governmental), which would support teachers for such study; and (e) the profession, which would recognize that such efforts were in its own best interests and in the best interests of the children it serves.

Such imaginative cooperation has not always characterized education, but certainly the time has come for educators to work together to improve schooling in ways that will benefit the public, not only themselves. Without such initiative from educators, lay persons in legislatures and elsewhere will determine the changes, and there is no evidence to date that such changes will be preferable to ones shaped by educators. Both will be political, but the essence of good politics is to have many of the relevant groups participating in the political process.

Although we have not determined the best means for preparing teachers, we do know much more about the process of learning and how to enhance it than we have incorporated into most professional programs. Underlying an effort to enhance pedagogical effectiveness must be familiarity with the subject to be taught. Typically certification requirements have aimed at coverage or comprehensiveness in mandating broad areas of a discipline to which the prospective teacher should be exposed. Alternatively, we argue that the teacher initially needs intensive knowledge of the subject; breadth can come later. Only with some modicum of intensive knowledge of a subject can come the enthusiasm for studying it that ought to be characteristic of all teachers. Everyone, obviously, will not feel equally strongly about the beauty of hydrogen bonds or iambic pentameter, but all teachers need a passion for some aspect of their subject. Such passion is the fuel for future learning. It is likely to occur only if one has studied the discipline deeply enough to find some element that truly captures one's imagination. Such involvement is unlikely to come from survey courses.

Many have had the experience of teaching a course on a subject which they have never formally studied. In such circumstances it is imperative that they have an understanding of the context of the subject of the course in the larger discipline in which the subject rests. Without that understanding of the relation of the subject to the larger laws or structure of the discipline, one is condemned to superficiality or error. For example, if teachers are asked to teach a history course on mid-twentieth-century America, it is quite likely that if they graduated from college in the fifties or the sixties they would never have had the benefit of such a course themselves although they had extensive preparation in American history prior to World War II. From that substantial prior training in history one should have learned how to organize and locate material for such a new course; to follow rules of evidence for historical interpretation; to recognize and understand differences in interpretation among commentators on the period; and to help students recognize that issues salient in one period may not be similarly salient in another. That prior historical training, then, enables one to offer a course on a subject that one had not studied formally but which one had the tools to handle. Such background is very different from that of mathematics teachers similarly asked to teach twentieth-century American history courses on the seemingly plausible ground that since they had lived through the mid-twentieth century in America as sentient adults, then they had the necessary qualifications. The likelihood is that they would have recollections, intelligence, and pedagogical skill but not historical insight. That is not enough.

The example of the mathematician teaching mid-twentieth-century American history may seem a bit extreme, but it illustrates a general point, which is that teachers are regularly asked to teach something about which they have a surface familiarity but no fundamental understanding of the discipline. How many elementary teachers, for example, teach arithmetic with complete familiarity with the number facts of addition, subtraction, multiplication, and division but with no comparable understanding of the organizing principles of number theory? Probably a good many do, and probably a good many children thus learn accurately how to add, subtract, multiply, and divide. What does not happen, however, and what is crucially important, is that for those children who do not easily master the number facts, the teacher has few, if any, intellectual resources to explain to the children WHY the numbers work together in the way that they do, thus eliminating a pedagogically effective way of helping them overcome their difficulty in learning the number facts themselves. More commonly, when children must master multiplication and division of fractions, most do so with memorization of when to invert divisors but without any comprehension of WHY it is necessary to do so. The explanation is in terms of the rule to follow, not in terms of why that rule works. Some children will simply memorize the rule and be done with it; a few will figure out on their own the basis for the rule; but others, too many others, will simply not get it, and the teacher will be bereft of the understanding that would translate into explanations which help more of them to grasp the assignment. The teacher, then, must not only be able to do the problems but also be able to understand why the problems are solved the way they are.

Recently Robert E. Apfel, head of the mechanical engineering department at Yale University, criticized what passes for science education in the elementary school: "Why should a fifth grader know it takes longer for Uranus to travel around the Sun than the Earth? Or that a light year is *defined* as a measure of distance. These questions don't test science literacy, but memorization, which tells *about* science, rather than encouraging exploration of the three-dimensional natural world. Why not have the second grader describe his or her rock so carefully that a classmate can find it among many similar ones? Why not have sixth graders, equipped with strong weights, a stopwatch and a ruler, write about or give an oral presentation on what determines the period of a pendulum? These simple examples illustrate ways of combining the process of science with evaluation" (Apfel, 1985).

Apfel, of course, is correct in preferring such direct experience with science over the diluted study that comes through a text. Nonetheless, the answer to Uranus' travel or the definition of a light year can be found easily by the teacher who is not knowledgeable about science, who has only a surface familiarity with the subject. Helping students identify rocks accurately or explaining the workings of a pendulum requires a much deeper understanding of geology or physics than does science presented via the textbook, and many elementary teachers do not have that deeper understanding of science.

If Fletcher Watson is correct that "The teacher in the classroom is the image of science before the pupils" (Watson, 1983, p. 50) then, unfortunately, many students perceive an "answer giver" as something indistinguishable from, or at best an extension of, the textbook they stuff into their lockers immediately after class. Not only do Stake and Easley report that "Over 90% of the science teachers in a sample of 12,000 teachers said their instructional materials were the *heart* of their teaching curriculum 90–95% of the time" (Stake & Easley, 1978, p. 13:66), they add that "As we saw it, teachers relied on, teachers believed in, the textbook. Textbooks and other learning materials were not used to support teaching and learning, they were *the instrument* of teaching and learning" (Stake & Easley, 1978, p. 19:6). Surface familiarity with a subject, then, ought not to entitle one to teach it, even at a rudimentary level. A deeper grasp of the discipline is needed; too often neither is it provided by the college or university program of studies nor is it assessed by examinations.

Zoeller and Watson (1974) have elaborated on the concept of a "curriculum-proof" teacher in science education. By this term, they explicitly reject attempts to demean, minimize, or automatize teachers through the creation of "teacher-proof" curricula, and recognize the centrality of teachers' role in the educative process. Curriculum-proof teachers, they argue, are those: (a) who are "independent enough to be dominated by no single course outline or sequence" (Zoeller & Watson, 1974, p. 96) but rather creatively and flexibly tailor the curricular materials to the needs of their students; (b) who use different means to achieve similar goals and vary their instructional strategies for different groups and individuals; and (c) who are capable of intelligent decision making, encourage their students to do likewise, and expect both thoughtful questions as well as answers rooted in appropriate evidence. For Zoeller and Watson, the "curriculum-proof teacher seems to be a logical step toward the achievement of. . . the curriculum-proof citizen, who is the ultimate goal of a relevant science curriculum" (Zoeller & Watson, 1974, p. 95).

This hypothetical curriculum-proof science teacher may not be the visionary notion that skeptics would have us believe—many of the teachers identified in the NSTA Search for Excellence initiative exemplified these characteristics. In fact, Bonnstetter, Penick, and Yager (1983, p. 33) have consolidated their data into a list of 20 characteristics applicable to a search for excellent teachers. They note that teachers of exemplary science programs create a stimulating and accepting environment, systematically providing for students' cognitive and affective growth; they do not consider the classroom walls as a boundary and frequently use societal issues as a conceptual focus; they stress scientific literacy; they want their students to apply knowledge and challenge them to do so; they are flexible in their use of time, curricular approach, and expectations, and are themselves "models of active inquiry"; they are concerned with improving their communicative skills and work well with parents, administrators and community leaders.

Knowledge of the subject matter is essential, but it is not enough. Two additional dimensions are vital for good teachers. The first is understanding cognitive, developmental, and cultural influences on learning. Knowledge of how persons learn—the varied means by which they learn, their varied receptivity for learning, and the explanation for those variations—is essential. Ultimate understandings can not be expected, but partial understandings are, and most of all, appreciation of the significance of the issue can be expected. The corollary issues are "How that learning can be augmented, enhanced, and facilitated?" or expressed negatively, "How is that learning impeded?" We now recognize variation in children's learning styles, a variation influenced by different cognitive styles and different developmental stages. We know, too, that family, peer, and cultural expectations vary greatly. To be aware of variance, however, is not to accept differential performance. Rather, it requires accommodating the teacher's style to meet the children's differences rather than simply letting the schooling process reinforce some children's aptitudes for learning and others' disinclination. When a child fails to learn the material, the teacher's task is to understand why the child did not learn the first time so that the obstacles to learning can be removed.

In addition to knowledge of the subject matter and of differences in children's learning, teachers must also act in accordance with their knowledge and understanding. To be pedagogically effective, teachers must be able to incorporate both the essence of their subject and its amplification in ways that will make it accessible to the children. Those are monumentally complex actions to expect of teachers, many of whom are still trained to provide essentially a "take it or leave it" approach to curricular presentations.

Science teachers, in particular, are said to use an insufficient repertoire of instructional strategies and evaluative procedures in the classrooms. Rather than alternate their strategies in accordance with the topic under discussion or the specific instructional objectives or student learning styles, most science teachers adopt a traditional lecture-recitation format while using laboratory and other hands-on experiences for verification of lecture or textbook conclusions.[6]

So far the colleges and universities who ostensibly educate these teachers are much better at analyzing differences in student receptivity for learning than we are at either helping teachers understand the disciplines to be taught in pedagogically fruitful ways or in assisting them in combining their knowledge of children and the subjects in effective ways. Much more effort aimed at helping teachers adapt their pedagogy is essential. Such adaptation is necessary for the teacher-centered school because in it one is moving beyond a simple recognition of differences among children to a profound acknowledgment of the teacher's responsibility to vary his or her pedagogical strategy in dealing with students.

In this regard the renewed emphasis on technology and its potential for enhancing learning may prove helpful. We have yet to see. As we think more about curricular questions and various modes of presenting material to students in pedagogically effective ways, we recognize the need for collaborative work with specialists in several areas: scholars in academic areas such as chemists, physicists, mathematicians; psychologists expert in cognition and development; thoughtful and experienced teachers in the school subjects; educators interested in aiding teachers; administrative personnel; and persons knowledgeable about developing software. Such cooperative endeavors need to be just that, and colleges and universities are good places to organize such groups.

In the past we have sometimes believed that one group of participants, such as the subject matter specialist or the psychologist, should have the preeminent role as a consequence of his or her presumed expertise. What we have learned, however, is that pedagogical effectiveness rests not upon one of these specialists but upon the interaction of all of them. Thus, in order to work thoughtfully and creatively in the combined area of curriculum development and pedagogical effectiveness we need the joint efforts of such groups, whose composition will vary with the specific subjects to be addressed. The success of the enterprise is likely to depend on our ability to be flexible in bringing together interested and informed participants for the duration of the exercise.

Such expertise in pedagogy is relatively unimportant in teaching those who learn easily, but it is essential for the majority of students for whom learning what adults and the society want them to know does not come easily. Skill is in short supply and has been underappreciated and misunderstood in recent years, largely because we the society and thus

[6]See, for example, references by DeRose, Lockard, and Paldy (1979), Kyle (1984b), and Shymansky (1980).

the educators among us have believed that it was neither necessary nor important for all persons to achieve substantial levels of academic learning. Now we are changing our minds, and we need to give more attention to the means of increasing pedagogical effectiveness as part of the education of teachers.

Let us conclude this section on teacher preparation by observing the overpowering significance of a small cadre of extraordinarily effective teachers in a school building. Unless each building has such a group of expert teachers, even though it may be small, the remaining teachers, be they experienced or inexperienced, have no resident models for their own performance. Few factors are more conducive to assisting a teacher to become more effective than the availability of a colleague who is effective and who is willing to help. Normally the teachers who are outstanding in enhancing children's learning are informally recognized by both their colleagues and by the administration, although too frequently they are not rewarded for their excellence. Sometimes their expertise is a consequence of their formal study; often, particularly in recent years when opportunities for formal study for experienced teachers have diminished, it is a consequence of informal study. Nonetheless, the existence of such a cadre is vitally important in setting the tone of expected teacher performance in the building. One of the most troubling consequences of the recent departures of able persons from teaching is the reduction of those small, expert groups. The shift of able women from teaching to other professions has further eroded that group. An issue for all of us remains to assure that each building has at least a small, and preferably a large, group of recognized pedagogically effective teachers. They are vital in establishing the standard of instruction throughout the building.

Consensus About Goals

Finally, society at large and the educators within it must agree on what our schools are expected to do, and both the lay members of the community and the professional educators must collaborate to achieve this agreed-upon end. At the moment both the agreement about goals for the schools and means of achieving them are a little nebulous. In most political processes there is a legitimate and often desirable ambiguity about goals since a premature specificity often reduces the participation of some in the coalition. In schooling, however, which is indeed influenced by the larger politics of American life, we need to articulate with greater clarity what we are trying to do. We need to recognize that schools are not multipurpose social institutions designed to aid young people in a variety of ways, all equally important. Rather, schools are institutions with a rank order of priorities for dealing with the young, and at the top of the list must be effective instruction in academic material.

This commitment to a hierarchy of priorities for schooling is especially important for the children of the poor who, if they are not instructed in school, are less likely than the children of the rich to have compensatory instruction in the private sector. The current Socialist Minister of Education in France, Jean-Pierre Chevenement, argues, "A good school with high standards is more democratic than a lax school. It is a paradox that many intellectuals don't understand" (Chevenement, 1985). In the United States we have often believed that if we did not hold some children to as high a standard as we held others, or if we did not expect as much as some children—often based on differences in their socio-economic or ethnic origins—as we did of others, then we were doing a favor to the ones of whom we were expecting less. We were not "pressuring" them but rather "allowing them to choose." We have come to see that it is of no benefit either to the child or to the society to insist that some become literate and to leave the option of illiteracy open to others. That is not a realistic choice for America today.

This issue is especially pointed for science education, which during most of the post-Sputnik period has been regarded as specialized education for the academically gifted, particularly those who might become scientists. High schools prided themselves on their advanced placement offerings in physics, chemistry, biology, and calculus. Only a few benefited from these courses, but for those who did and for the teachers who taught them they were frequently intellectually challenging experiences.

Today, however, our concerns about education generally and science education, specifically, are more pervasive. We are increasingly concerned with the academic learning or lack of academic learning of the children in the middle, not simply the future scientists. At a recent meeting convened by the National Science Board Commission on Precollege Education in Mathematics, Science, and Technology (1982) representatives from a variety of institutions—including Big Ten universities, the military academies, historically Black colleges, community colleges, MIT and Cal Tech, and traditional four-year liberal arts colleges— informally agreed that for all their entering students they sought two academic characteristics: strong competence in mathematics up to but not including calculus, and vigorous interest and enthusiasm about science but not advanced placement courses in specific sciences. If such views were widely accepted by both high school and colleges, the consequences for science and mathematics teaching would be immense. Fundamentally, it would emancipate science teachers from differentiated science courses for the college bound and the noncollege bound and allow them to exercise greater creative energies on developing science courses that would indeed intrigue a broad cross-section of students. Such efforts would test the ingenuity of the teachers.

How we accomplish such academic learning for all is the issue at hand. To do so would be a fundamental change for this and all other societies. We have not done this yet, and neither have the French, despite the Minister's statement, or any other nation. Achievement of this illusive goal rests on the interrelationship of the four issues discussed earlier: improving working conditions for teachers, attracting able people to teaching, preparing teachers to be pedagogically effective with all children, and gaining societal consensus about the academic goals of schooling. We know that when only one or two of these changes occurred (the Master of Arts in Teaching program, for example, was an excellent combination of attracting able people to teaching and preparing them well but it did not change working conditions in the schools nor did the society agree on academic ends of schooling), without support of the other two, fundamental reform did not occur. We need that fundamental reform now.

Conclusion

The basic task of teachers is to nurture and enhance the young. Few adult jobs are more important and more challenging than that. Hence, we can be cautiously optimistic about the willingness of society to accept the necessity to change teachers' working conditions, to encourage able persons both traditional and untraditional to teach, and to urge colleges and universities to help teachers to become truly pedagogically effective, thus justifying a change from child-centered schools to teacher-centered schools.

References

Apfel, R. E. (1985, May 8). Is science teaching turning students off? *The New York Times*.

Atkin, J.M. (1983, Spring). The improvement of science teaching. *Daedalus*, pp. 167–187.

Atkin, J.M., & House, Ernest R. (1981). The federal role in curriculum development, 1950–80. *Education Evaluation and Policy Analysis, 3* (5), 5–36.

Bellah, R., Madsen, R., Sullivan, W. M., Swidler, A., & Tipton, S. M. (1985). *Habits of the heart, individualism and commitment in American life* (p. 290). Berkeley, CA: University of California Press.

Bethel, L. J. (1984). Is there a shortage of science and mathematics teachers? In D. Holdzkom & P.B. Lutz (Eds.), *Research within reach: Science education* (pp. 143–157). Charleston, WV: Appalachia Educational Laboratory.

Bonnstetter, R. J., Penick, J. E., & Yager, R. E. (1983). *Teachers in exemplary programs: How do they compare?* Washington, DC: National Science Teachers Association.

Chevenement, J. (1985, June 18). French Socialist takes a conservative stand. *The New York Times*.

Cremin, A. (1961). *The transformation of the school.* New York: Vintage.

DeRose, J. V., Lockard, J. D., & Paldy, L. G. (1979, April). The teacher is the key: A report on three NSF studies. *The Science Teacher*, pp. 31–37.

Dow, P. B. (1980). *Innovation's perils.* Unpublished doctoral dissertation, Harvard University, Cambridge.

Evertson, C., Hawley, W., & Zlotnik, M. (1984). *The characteristics of effective teacher preparation programs: A review of the research* (pp. 2, 15). Nashville, TN: Vanderbilt University Press.

Feistritzer, C. E. (1983). *The American teacher.* Washington, DC: Author.

Friendly, J. (1985, August 31). After lag, teachers start to catch up on pay. *The New York Times*, p. 1.

Gilligan, C. (1982). *In a different voice.* Cambridge, MA: Harvard University Press.

Graham, P. A. (1967). *Progressive education: From Arcady to academe.* New York: Teachers College Press.

Graham, P. A. (1984, Fall). Schools: Cacophony about practice, silence about purpose. *Daedalus*, pp. 29–57.

Harms, N. C., & Yager, R. (Eds.). (1981). *What research says to the science teacher* (Vol. 3). Washington, DC: National Science Teachers Association.

Helgeson, S. L., Blosser, P. E., & Howe, R. W. (1977). *The status of precollege science, mathematics, and social science education: 1955-1975; Vol. 1: Science education.* Washington, DC: National Science Foundation.

Hurd, P. DeH. (1983). The state of precollege education in mathematics and science. *Science education, 67* (1), 55–67.

Hurd, P. DeH. (1983, December/1984, January). Science education: The search for a new vision. *Educational Leadership*, pp. 20–22.

Jackson, P. (1983, Spring). The reform of science education. *Daedalus*, p. 157.

Kyle, W. C., Jr. (1984a). What became of the curriculum development projects of the 1960s? In D. Holdzkom & P. B. Lutz (Eds.), *Research within reach: Science education* (p. 19) Charleston, WV: Appalachia Educational Laboratory.

Kyle, W. C., Jr. (1984b). What implications for science education can be drawn from research on effective schools and classrooms? in D. Holdzkom & P. B. Lutz (Eds.), *Research within reach: Science education* (pp. 123–141). Charleston, WV: Appalachia Educational Laboratory.

Merseth, K. K. (1985, April 1). *Rear admirals and biochemists: Why do they want to teach high school?* Paper presented at the meeting of the American Education Research Association Meeting, Chicago, IL.

National Center for Education Statistics. (1983). *Digest of education statistics 1983–1984* (Table 8, p. 13). Washington, DC: Author.

National Commission on Excellence in Education. (1983). *A nation at risk: The imperative for educational reform.* Washington, DC: Author.

National Education Association (NEA) Research office (1985) Washington, DC: Author. (private communication).

National Science Board Commission on Precollege Education in Mathematics, Science, and Technology. (1982, November 16). Meeting (Washington, DC). (private communication).

National Science Board Commission on Precollege Education in Mathematics, Science, and Technology. (1983). *Educating Americans for the 21st century: A plan of action for improving mathematics, science,* *and technology education for all American elementary and secondary students so that their achievement is the best in the world by 1995.* Washington, DC: Author.

Penick, J. E., & Yager, R. E. (1983). The search for excellence in science education. *Phi Delta Kappan, 64*, 621–623.

Powell, A., Farrar, E., & Cohen, D. K. (1985). *The shopping mall high school.* Boston: Houghton Mifflin.

Ravitch, D. (1983). *The troubled crusade.* New York: Basic Books.

Rowe, M. B. (1983, Spring). Science education: A framework for decision-makers. *Daedalus*, p. 136.

Rugg, H. O., & Shumaker, A. (1928). *The child-centered school.* Yonkers-on-Hudson, NY: World Book Co.

Shymansky, J. A. (1980). How teaching strategies affect students. In M. B. Rowe (Ed.), *What research says to the science teacher* (Vol. 1). Washington, DC: National Science Teachers Association.

Shymansky, J. A., & Aldridge, B. G. (1982, November). The teacher crisis in secondary school science and mathematics. *Educational Leadership*, pp. 61–62.

Shymansky, J. A., Kyle, W. C., Jr., & Alport, J. (1982, October). Research synthesis on the science curriculum projects of the sixties. *Educational Leadership*, pp. 63–68.

Sigda, R. B. (1983). The crisis in science education and the realities of science teaching in the classroom. *Phi Delta Kappan, 64*, 624–627.

Stake, R., & Easley, J. (1978). Case studies in science education. In *The status of precollege science, mathematics and social studies educational practices in U.S. schools: An overview and summaries of three studies* (Report No. SE 78-71). Washington, DC: National Science Foundation.

Twentieth Century Fund Task Force on Federal Elementary and Secondary Education Policy. (1983). *Making the grade.* New York: Twentieth Century Fund.

Watson, F. G. (1983). Do we include essential aspects of science in our definition of school science? In F. K. Brown & D. Butts (Eds.), *Science teaching: A profession speaks* (p. 50). Washington, DC: National Science Teachers Association.

Weiss, I. R. (1978). *Report of the 1977 national survey of science, mathematics and social studies education.* Washington, DC: National Science Foundation.

Yager, R. E (1984). The major crisis in science education. *School Science and Mathematics, 84,* 189–198.

Yager, R. E., & Penick, J. E. (1984). What students say about science teaching and science teachers. *Science Education, 68,* (2), 143–151.

Yager, R. E., Aldridge, B. G., & Penick, J. (1983). In F. K. Brown & D. Butts (Eds.), *Science teaching: A profession speaks* (pp. 3-18). Washington, DC: National Science Teachers Association.

Yankelovich, D. (1981). *New rules, searching for self-fulfillment in a world turned upside down* (p. 250). New York: Random House.

Zoeller, U., & Watson, F. G. (1974). Teacher training for the second generation of science curricula: The curriculum-proof teacher. *Science Education, 58* (1), 93–103.

Appendices

A. Forum '85 Program

NFSS

FIRST ANNUAL

NATIONAL FORUM FOR SCHOOL SCIENCE

Forum '85
Science Teaching

October 10 and 11, 1985

The Shoreham Hotel
Washington, D.C.

Sponsored by the
Office of Science and Technology Education
of the
American Association for the Advancement of Science
with the support of
The Carnegie Corporation of New York

Thursday, October 10

8:00 a.m. Hampton Foyer	**Registration**
8:45 a.m. Hampton	**Welcome and Overview of the Forum** Audrey B. Champagne, *Project Director, National Forum for School Science*
9:00 a.m. Hampton	**Session I: Science Teaching—Policy and Practice** Education reform attempts and outcomes □ Defining science teacher quality □ Roles and responsibility □ Current and future policy options Moderator: William D. Carey, *Executive Officer, AAAS* Speakers: Newt Gingrich, *Member, U.S. House of Representatives (R-GA)* George Pimentel, *Director, Laboratory of Chemical Biodynamics, University of California, Berkeley* Patricia A. Graham, *Dean, Harvard Graduate School of Education*
10:15 a.m.	**Break**
10:30 a.m.	**Discussion Sessions**
Council	"Data Collection and Analysis for Informed Science Education Policy-Making" Discussion leader: Iris Weiss, *Senior Educational Research Scientist, Research Triangle Institute*
Calvert	"Mobilizing a Community to Improve Science Instruction" Discussion leader: Richard A. Wallace, Jr., *Superintendent, Pittsburgh Public Schools*
Cabinet	"Who Is Responsible for Science Teacher Supply and Quality?" Discussion leader: Arthur E. Wise, *Director, Center for the Study of the Teaching Profession, The Rand Corporation*
Capitol	"Effects of Hiring and Certification Policies on Classroom Quality" Discussion leader: Alphonse Buccino, *Dean of the College of Education, The University of Georgia*
Caucus	"Legislative, Administrative, or Professional Control of Teaching Practice?"

Discussion leader: Gerald Skoog, *Chair of Secondary Education, Texas Tech University, and President, National Science Teachers Association*

12:15 p.m. **Luncheon**

Hampton Address: "The Impact of Artificial Intelligence on School Science"

Pamela Surko, *Member of the Technical Staff, AT&T Bell Laboratories, and President, Association of Women in Science*

2:30 p.m. **Session II: The Social, Economic, and Political**

Hampton **Environment of Teaching**

Factors that affect the supply and quality of science teachers ☐ Wise resource utilization ☐ Social costs of ineffective teaching

Moderator: F. James Rutherford, *Chief Education Officer, AAAS*

Speakers:

Edward Harvey, *Professor of Sociology, Ontario Institute for Studies in Education*

Erich Bloch, *Director, National Science Foundation*

M. Carl Holman, *President, National Urban Coalition*

3:45 p.m. **Break**

4:00 p.m. **Discussion Sessions**

Calvert "Caught Between Excellence and Equality: Occupational and Professional Issues for Science Teachers"

Discussion leader: Lorna Marsden, *Professor of Sociology, University of Toronto, and Member of the Canadian Senate*

Caucus "Making the Best of Scarce Human Resources"

Discussion leader: Pamela Surko, *Member of the Technical Staff, AT&T Bell Laboratories*

Council "Working Conditions That Promote Effective Science Teaching"

Discussion leader: Margret Andersen, *Chemistry Teacher, Dennis-Yarmouth Regional High School*

Cabinet "What Happens to Science Teaching When Career Alternatives for Women and Minorities Increase?"

Discussion leader: To be announced

Capitol "Making Good Laboratory Teaching Feasible"

Discussion leader: Bassam Z. Shakhashiri, *Assistant Director for Science and Engineering Education, National Science Foundation*

5:15 p.m. **Adjournment**

5:45 p.m. **Reception**
Executive

Friday, October 11

8:00 a.m. **Registration**
Hampton Foyer

9:00 a.m. **Session III: Setting and Maintaining Standards of Quality for Science Teaching**
Hampton

Factors that determine science teacher efficacy □ Models of science teacher education □ Assessing teacher quality □ Balancing scientific and professional training

Moderator:
Richard Berendzen, *President, The American University*

Speakers:
Paul E. Peterson, *Director, Governmental Studies, The Brookings Institution*
Gordon Ambach, *Commissioner of Education for the State of New York*
Amado J. Sandoval, *Chemistry Teacher, Centennial High School*

10:15 a.m. **Break**

10:30 a.m. **Discussion Sessions**

Calvert "Teaching Teachers to Teach Science Well, Part I: Preservice Education"

Discussion leader: Michael Fultz, *Instructor, Harvard Graduate School of Education*

Embassy "Teaching Teachers to Teach Science Well, Part II: Continuing Education for Teachers"
Discussion leader: Robert Rosenbaum, *Professor of Mathematics, Wesleyan University*

Hampton "What Is a Good Science Teacher?"
Discussion leader: Diana Marinez, *Professor and Chair of the Department of Natural Science, Michigan State University*

Cabinet "Assessing Science Teacher Quality"
Discussion leader: Doris S. Sandoval, *Chemistry Teacher, Springbrook High School*

Capitol "Quality Science Teaching at the Elementary Level"
Discussion leader: Alice Moses, *Associate Program Director for Leadership Activities for Precollege Teachers, National Science Foundation*

12:15 p.m. **Luncheon**

Diplomat Summary and Recommendations for Action
To be announced

Closing Remarks
Audrey B. Champagne, *Project Director, National Forum for School Science*

2:00 p.m. **Adjournment**

B. Participants

Participants

ISABEL ABRAMS, Curriculum Innovations
ANDREW AHLGREN, AAAS, 1333 H Street, N.W., Room 1019, Washington, DC 20005
LISA K. ALEXANDER, Addison Wesley Publishing Company, 2725 Sand Hill Road, Menlo Park, CA 94025
GARY G. ALLEN, Native American Science Education Association, 1228 M Street, N.W., Washington, DC 20009
GORDON AMBACH, Commissioner of Education, 111 Education Building, Albany, NY 12234
MARGRET ANDERSEN, (Dennis-Yarmouth Regional High School), 10 Rawson Street, East Falmouth, MA 01085
RONALD D. ANDERSON, University of Colorado, Campus Box 249, Boulder, CO 80309
LUC A. ARNOULD, Embassy of Belgium, 3330 Garfield Street, N.W., Washington, DC 20008
JOHN A. BARTLEY, 111 W. Leamy Avenue, Springfield, PA 19064
SELMA BAXT, AAAS, 1333 H Street, N.W., Room 809, Washington, DC 20005
A[illegible]N BAY, Smithsonian Institution, Washington, DC 20560
KATHLEEN BEAUCHAT, University of Arizona, Tucson, AZ 85717
CHARLES W. BEEHLER, Rose Tree Media School District, 901 N. Providence Road, Media, PA 19063
HEATHER A. BE[illegible]L, South African Office of Science & Technology, 4801 Massachusetts Ave., N.W. #350, Washington, DC 20016
ROBERT J. BERNARDI, (Holliston Public Schools), P.O. Box 112, 48 Taft Street, Milford, MA 01757
RICHARD BERENDZEN, The American University, 4400 Massachusetts Avenue, N.W., Washington, DC 20016
PENNY L. BERNSTEIN, (Wetlands Institute), 163 Mt. Kemble Avenue, Morristown, NJ 07960
RICHARD M. BERRY, National Science Foundation, 1800 G Street, N.W., Room 504, Washington, DC 20550
MARIANNE B. BETKCUSKI, (University of North Florida), 2317 Costa Verde, #201, Jacksonville Beach, FL 32250
JOHN V. BETZ, (University of South Florida), FAO 126, 4202 East Fowler, Tampa, FL 33620
HELEN L. BISHOP, American Society For Microbiology, 1913 I Street, N.W., Washington, DC 20006
ERICH BLOCH, National Science Foundation, 1800 G Street, N.W., Washington, DC 20550
PATRICIA BLOSSER, (The Ohio State University) 2606 Brandon Road, Columbus, OH 43221

ROBERT V. BLYSTONE, Trinity University, 715 Stadium Drive, San Antonio, TX 78284

RAY F. BOEHMER, University of Illinois, 307 Engineering Hall, 1308 W. Green, Urbana, IL 61801

WILLIAM H. BOLLES, Pennsylvania Department of Education, 333 Market Street, Harrisburg, PA 17126

ANNETTE BOWER, Mount St. Mary's College, 12001 Chalon Road, Los Angeles, CA 90049

REGINA P. BOWLING, Huntsville City Schools, Huntsville, AL 35904

JANE BREWSTER, TRW, 1000 Wilson Boulevard, Suite 2700, Arlington, VA 22209

BETSY S. BROWN, Carnegie Forum on Education and the Economy, 1001 Connecticut Ave., N.W., Suite 301, Washington, DC 20036

ALPHONSE BUCCINO, University of Georgia, College of Education, G-3 Aderhold Hall, Athens, GA 30602

JOHN W. BUTZOW, Indiana University of Pennsylvania, 104 Stouffer Hall, Indiana, PA 15705

RODGER W. BYBEE, Biological Sciences Curriculum Study, 1115 N. Cascade Avenue, Colorado Springs, CO 80903

JOANNE CAPPER, Council of Chief State School Officers, 400 North Capitol Street, N.W. #379, Washington, DC 20001

ANTHONY J. CARÇIERI, (Rhode Island Board of Regents), 22 Hayes Street, Providence, RI 02908

WILLIAM D. CAREY, AAAS, 1333 H Street, N.W., Room 1039, Washington, DC 20005

KARL C. CARTER, Michigan State University, Natural Science Department, 100 North Kedzie Lab, East Lansing, MI 48824

AUDREY B. CHAMPAGNE, AAAS, 1333 H Street, N.W., Room 1033, Washington, DC 20005

RICHARD C. CLARK, Minnesota State Department of Education, Capitol Square Building, St. Paul, MN 55101

HENRY N. COLE, (The Langley School) 1305 S. Monroe Street, #1, Arlington, VA 22204

FRANK COLLEA, California State University System, 400 Golden Shore, Long Beach, CA 90802

GEORGE COLLIER, Hunterdon Central High School, Route 31, Flemington, NJ 08822

NANCY J. COOKSY, Washington D.C. Public Schools, Eastern High School, Washington, DC.

BOB E. CRAVEN, Houghton Mifflin Company, One Beacon Street, Boston, MA 02108

GLENN A. CROSBY, Department of Chemistry, Washington State University, Pullman, WA 99164

BURNETT CROSS, 170 East Hartsdale Avenue, Hartsdale, NY 10530

PAT CURLIN, AAAS, 1333 H Street, N.W., Room 1057, Washington, DC 20005

ROSI DAGIT, The Langley School, 1411 Balls Hill Road, McLean, VA 22101

THOMAS F. DALLMAN, (University of California, Riverside), 500 Alta Mesa Street, Riverside, CA 92507

JAMES A. DAVID, American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017

E. KAY DAVIS, (Fernbank, Inc.) 1788 Ponce de Leon Avenue, NE, Atlanta, GA 30307

NORMAN F. DESSEL, San Diego State University, Natural Science Department, San Diego, CA 92182

LUIS ANGEL DIAZ-HERNANDEZ, Department of Education, Puerto Rico

JOHN S. DICKEY, 204 Heroy Geology Laboratory, Syracuse University, Syracuse, NY 13244

ANTHONY DIMAGGIO III, Loyola University, 6363 St. Charles Avenue, New Orleans, LA 70118

PAMELA DRONKA, ASCD Update, 225 N. Washington Street, Alexandria, VA 22314

[illegible] [illegible]IGER, National Science Foundation, 1800 G Street, N.W., Washington, DC 20550

PATRICIA D[illegible], AAAS, 1333 H Street, N.W. Room 1026, Washington, DC 20005

JOHN B. DRUGG, (Columbia University Teachers College), 162 Bedford Avenue, #4, Brooklyn, NY 11211

E. ALDEN DUNHAM, Carnegie Corporation of New York, 437 Madison Avenue, New York, NY 10022

JULIE EARLY, AAAS, 1333 H Street, N.W., Room 1013, Washington, DC 20005

DONALD C. EDINGER, Grand Valley State Colleges, Allandale, MI 49401

KARIN EGAN, Carnegie Corporation of New York, 437 Madison Avenue, New York, NY 10022

ADELA S. ELWELL, (Science Museum of Minnesota), Neilson Spearhead Center, Rt. 2 Box 295AA, Bemidji, MN 56601

JOHN FALK, Smithsonian Institution, Washington, DC 20560

JOHN B. FERGUSON, Department of Biology, Bard College, Annandale-On-Hudson, NY 12504

THOMAS A. FERGUSON, Fairfax County Public Schools, 3705 Cres[illegible] Drive, Annandale, VA 22003

FRED L. FIFER, University of Texas at Dallas, P.O. Box 830688/Mail Station FN 32, Richardson, TX 75083

FREDERICK W. FISHER, Abington Senior High School, Abington, PA 19001

SUSAN M. FITZPATRICK, (Yale University), 388 Whitney Avenue, 3rd Floor, New Haven, CT 06511

JOHN M. FOWLER, Triangle Coalition for Science and Technology Education, 1742 Connecticut Avenue, N.W., Washington, DC 20009

SHIRLEY FOX, National Institute for Work and Learning, 1302 18th St., N.W., Washington, DC 20036

G. EARLE FRANCQ, Indiana Department of Education, Room 229, State House, Indianapolis, IN 46204

WILLIAM T. FRANZ, Department of Physics, Randolph-Macon College, Ashland, VA 23005

MARY P. FRYAR, Fernandina Beach High School, P.O. Box 1228, Fernandina Beach, FL 32034

MICHAEL FULTZ, Harvard Graduate School of Education, Cambridge, MA 02138

MYNGA K. FUTRELL, (California State University, Sacramento), 513 Messina Drive, Sacramento, CA 95819

DARREL W. FYFFE, Bowling Green State University, Department of Educational Curriculum, Bowling Green, OH 43404

CHARLES I. GALE, (Montgomery County Public Schools), 13604 Russett Terrace, Rockville, MD 20853

EUGENE GENNARO, University of Minnesota, Minneapolis, MN 55455

WALTER GILLESPIE, AAAS, 1333 H Street N.W., Room 1030, Washington, DC 20005

NEWT GINGRICH, U.S. House of Representatives, 1005 Longworth HOB, Washington, DC 20515

ALFRED J. GIRONDI, (West Shore School District), 2453 Berryhill Street, Harrisburg, PA 17104

FRED M. GOLDBERG, West Virginia University, Physics Department, 109 Hodges Hall, Morgantown, WV 26506

EVAN M. GOLDMAN, (National Education Association), 464 Churchill Road, Teaneck, NJ 07666

CONSTANCE H. GORDON, (Trinity College), 125 Michigan Avenue, N.E., Washington, DC 20017

KAREN K. GOTIMER, CBS Holt Rinehart & Winston, 383 Madison Avenue, New York, NY 10017

PATRICIA A. GRAHAM, Dean, Harvard Graduate School of Education, Cambridge, MA 02138

ANN GREGORY, Arlington Public Schools, 1426 N. Quincy Street, Arlington, VA 22207

LARRY GUTHRIE, Far West Laboratory for Educational Research & Development, 1855 Folsom Street, San Francisco, CA 94103

WALTER G. HAGENBUCH, (Colonial School District), 104Merion Avenue, Narberth, PA 19072

MARY HALLISY, Pacific Bell, 444 No. Capitol Street, Washington, DC 20001

JOHNNIE P. HAMILTON, Fairfax County Public Schools, 3705 Crest Drive, Annandale, VA 22003

BARBARA L. HANDELIN, MIT–Cancer Research Center, 40 Ames Street, E17–536, Cambridge, MA 02139

MARY B. HARBECK, (District of Columbia Public Schools), Instructional Services Center, 20th & Evarts Street, N.E., Washington, DC 20018

THOMAS HARROW, (University of Central Florida), P.O. Box 25000, Orlando, FL 32816

KATRINA HARTMAN, (University of Illinois at Chicago), 707 S. Ada, #2, Chicago, IL 60607

A. W. HARTON, IBM Corporation, P.O. Box 2150, Atlanta, GA 30055

EDWARD HARVEY, Ontario Institute for Studies in Education, 252 Bloor Street West, Toronto, Ontario Canada M5S 1A1

DAVID L. HAURY, Department of Education/Lincoln Filene Ct, Tufts University, Medford, MA 02155

JONITA S. HAYNES, Huntsville City Schools, Huntsville, AL 35904

CHERYLL M. HAWTHORNE, Lawrence Hall of Science, Centenniel Boulevard, Berkeley, CA 94720

STANLEY J. HERMAN, Board of Education, 341 S. Bellefield Avenue, Room 441, Pittsburgh, PA 15213

SISTER MARY HERTRICH, Ohio Dominican College, 1216 Sunbury Road Columbus, OH 43219

SHIRLEY A. HILL, (University of Missouri, Kansas City), 4820 W. 76th Street, Prairie Village, KS 66208

STANLEY J. HIPWOOD, Los Alamos National Laboratory, CPA–2; MS K705, Los Alamos, NM 87544

ROBERT HOLL, Addison-Wesley Publishing Co., Inc., 2725 Sand Hill Road, Menlo Park, CA 94025

M. CARL HOLMAN, National Urban Coalition, 1120 G Street, N.W., Washington, DC 20005

PAUL J. HOMSHER, Old Dominion University, Education Building, Room 218, Norfolk, VA 23508

SUSAN M. HOOPER, Education Week, 1255 23rd Street, N.W., Suite 775, Washington, DC 20037

NORMAN V. HORNER, Midwestern State University, Wichita Falls, TX 76308

LESLIE E. HORNIG, AAAS, 1333 H Street, N.W., Room 1032, Washington, DC 20005

CHARLES Y. HOYT, (Arizona Council of Engineering and Science Associations), 1220 East Nicolet Avenue, Phoenix, AZ 85020

MAGGIE HUME, Education Daily, P.O. Box 9672, Arlington, VA 22209

PAUL DEHART HURD, (Stanford University), 549 Hilbar Lane, Palo Alto, CA 94303
DALE E. INGMANSON, (San Diego State University), 5300 Campanile Drive, San Diego, CA 92041
FRAN JACKSON, University of Minnesota, Minneapolis, MN 55455
RACHEL E. JAMES, (Dowling Middle School), 5766 Schevers, Houston, TX 77033
CAROL A. JOHNSON. (Science Museum of Minnesota), Neilson Spearhead Center, Rt.2, Box 295AA, Bemidji, MN 56601
ELMIMA C. JOHNSON, National Science Foundation, 1800 G Street, N.W., Washington, DC 20550
KATHLEEN D. JOHNSON, Ohio Department of Education, 65 South Front Street, Room 1013, Columbus, OH 43215
MARTIN L. JOHNSON, National Science Foundation, 1800 G Street, N.W., Washington, DC 20550
KATHLEEN S. JOHNSTON, AAAS, 1333 H Street, N.W., Room 820, Washington, DC 20005
EDWARD E. JONES, Miami University, Center for Excellence in Mathematics and Science Education, Oxford, OH 45056
VINETTA JONES, University of North Carolina, Chapel Hill, NC 27514
CATHERINE A. JOSEPH, ABT Associates, Inc., 55 Wheeler Street, Cambridge, MA 02138
PHYLLIS KATZ, (Hands-On-Science Outreach), 17 Perry Street, Brookline, MA 02146
NELSON R. KELLOGG, Episcopal High School, 1200 North Quaker Lane, Alexandria, VA 22302
DAVID B. KELLOM, (Michigan Association of School Boards), 1600 Clover Lane, Midland, MI 48640
JOHN T. KEMP, Sun Company, Inc., 100 Matsonford Road, Radnor, PA 19087
MARY BETH KEY, St. Albans School, Washington, DC 20016
EDWARD C. KISAILUS, Canisius College, 2001 Main Street, Buffalo, NY 14208
LEOPOLD E. KLOPFER, University of Pittsburgh, 822 LRDC Building, Pittsburgh, PA 15260
AMIE B. KNOX, Camille and Henry Dreyfus Foundation, 10 Winding Lane, Greenwich, CT 06830
JANE KONRAD, Pittsburgh Regional Center for Science Teachers, 400 Forbes Avenue, Pittsburgh, PA 15213
JEAN OAK KRIEBS, (National College of Education), 18 S. Michigan Avenue, Chicago, IL 60603
LAWRENCE R. KRUPKA, Michigan State University, Natural Science Department, 100 North Kedzie Lab, East Lansing, MI 48824
DANIEL W. KUNZ, Commodore Computers, 1211 Connecticut Avenue, N.W., #800, Washington, DC 20036

FRANK J. KURTZ, Amoco Corporation, 200 East Randolph Drive, Mail #3705, Chicago, IL 60601

LESLIE E. LAHR, Mira Loma High School, 4000 Edison Avenue, Sacramento, CA 95821

DOUGLAS LAPP, National Academy of Sciences, 2101 Constitution Ave., N.W., Washington, DC 20418

ELLEN M. LAPPA, D.C. Heath and Company, 125 Spring Street, Lexington, MA 02173

JAMES W. LATHAM, Maryland Department of Education, 200 West Baltimore Street, Baltimore, MD 21201

FREDERICK C. LEAVITT, Dow Chemical Company, 1800 M Street, N.W. Washington, DC 20036

LEROY E. LEE, Wisconsin Academy of Science, 1922 University Avenue, Madison, WI 53705

EVELYN LENNER, Abington School District, Abington, PA 19001

DAVID E. LEVENTHAL, (Rohan-Woods School), 18 Arbor Road, St. Louis, MO 63132

MARSHALL M. LIH, National Science Foundation, 1800 G Street, N.W., Suite 1126, Washington, DC 20550

DORIS L. LITMAN, Board of Education, 341 S. Bellefield Avenue, Room 441, Pittsburgh, PA 15213

ARTHUR H. LIVERMORE, Triangle Coalition for Science and Technology Education, 1742 Connecticut Avenue, N.W., Washington, DC 20009

MADELEINE J. LONG, (Long Island University), 210 West 89th Street, New York, NY 10024

• JULIO E. LOPEZ-FERRAO, Department of Education, Puerto Rico

JAMES D. LUBBERS, (SUNY College of Fredonia), 113 Hamlet Street, Fredonia, NY 14063

KATHLEEN P. LYONS, University of Nevada, Las Vegas, 4505 S. Maryland Parkway, Las Vegas, NV 89154

WALTER B. MACDONALD, Educational Testing Service, Rosedale Road, 25–E, Princeton, NJ 08541

SHIRLEY MALCOM, AAAS, 1333 H Street, N.W., Room 1002, Washington, DC 20005

LINDA MANTEL, City College of New York, Convent Avenue, New York, NY 10031

DAVID R. MANYAN, University of New England, 11 Hills Beach Road, Biddeford, ME 04005

BRUCE I. MARGANOFF, New Jersey Department of Education, 225 West State Street CN 500, Trenton, NJ 08625

DIANA MARINEZ, North Kedzie Laboratory, Michigan State University, East Lansing, MI 48824

WILLIAM W. MARION, (CAST), 137 Lynn Avenue, Ames, IA 50010

JULIA M. MARSDEN, (University of Maryland), 9804 Inglemere Drive, Bethesda, MD 20817

LORENA V. MARTIN, Michigan State University, Natural Science Department, 100 North Kedzie Lab, East Lansing, MI 48824

R. BRUCE MARTIN, Chemistry Department, University of Virginia, Charlottesville, VA 22901

RALPH E. MARTIN, College of Education, Ohio University, Athens, OH 45701

MARIE P. MASTROPAOLO, United Teachers of Dade, 2929 S.W. 3rd Avenue, Miami, FL 33129

KEVIN MATTINGLY, Mountain School Program of Milton Academy, RR#1 Box 123F, Vershire, VT 05079

MARSHA MATYAS, AAAS, 1333 H Street, N.W., Room 1005, Washington, DC 20005

DIANE EBERT MAY, Husson College, Bangor, ME 04401

CLAUDE MAYBERRY, Science Weekly, Inc., P. O. Box 70154, Washington, DC 20088

MYRA J. MCAULIFFE, National Science Foundation, 1800 G Street, N.W., Room 504, Washington, DC 20550

EUGENE A. MCGINNIS, University of Scranton, Monroe Avenue, Scranton, PA 18510

DENNIS G. MCKEE, Laidlaw Brothers, 8020 W. Madison, River Forest, IL 60305

ROBERT E. MCNEMAR, (Columbus Public Schools), 5618 Worcester Drive, Columbus, OH 43232

PATRICIA J. MCWETHY, (National Association of Biology Teachers), 11250 Roger Bacon Drive, #19, Reston, VA 22203

LESLIE B. MERCER, Sewickley Academy, 315 Academy Avenue, Sewickley, PA 15143

JOHN R. MERGENDOLLER, Far West Laboratory for Educational Research and Development. 1855 Folsom Street, San Francisco, CA 94103

DALE G. MERKLE, Shippensburg University, FSC 109, Shippensburg, PA 17257

JANICE MERZ, AAAS, 1333 H Street, N.W., Room 1114, Washington, DC 20005

KATHI HANNA MESIROW, Office of Technology Assessment, U.S. Congress, Washington, DC 20510

DONALD J. METZ, Brookhaven National Laboratory, Office of Academic Relations-Building 185, Upton, NY 11973

E. GERALD MEYER, University of Wyoming, Box 3992, University Station, Laramie, WY 82071

EDWARD H. MEYER, Wilton High School, 395 Danbury Road, Wilton, CT 06897

JON D. MILLER, Public Opinion Laboratory, Northern Illinois University, Dekalb, IL 60115

FLOYD A. MITTLEMAN, Glenbrook North High School, 2300 Shermer Road, Northbrook, IL 60062

WILLIAM N. MOORE, CBS Educational & Professional Publishing, 383 Madison Avenue, New York, NY 10017

DAVID D. MORAN, Sigma XI–The Scientific Research Society, 345 Whitney Avenue, New Haven, CT 06511

JANICE S. MORRISON, Hathaway Brown School, 19600 No. Park Boulevard, Shaker Heights, OH 44122

ALICE MOSES, National Science Foundation, 1800 G Street, N.W., Washington, DC 20550

WAYNE A. MOYER, Franklin Institute, 20th and the Parkway, Philadelphia, PA 19103

SALVATORE J. NATOLI, Association of American Geographers, 1710 16th Street, N.W., Washington, DC 20009

LUCY M. NEWMAN, (Albuquerque Retired Teachers Association), 3325 Hastings N. E., Albuquerque, NM 87106

RICHARD E. NYGREN, (Argonne National Laboratory), U.S. Departmentof Energy, G226, ER–50, Washington, DC 20545

ERIN A. O'CONNELL, CIBA-GEIGY Corporation, 444 Saw Mill River Road, Ardsley, NY 10502

TIMOTHY O'SULLIVAN, CFC, Iona College, 715 North Avenue, New Rochelle, NY 10801

PATRICK L. ODELL, University of Texas at Dallas, Box 830688, Richardson, TX 75080

W. FREDERICK OETTLE, National Science Foundation, 1800 G Street, N.W., Washington, DC 20550

MARY LOUISE ORTENZO, George Washington University, 2201 G Street, N.W., Washington, DC 20052

JOHN J. PADALINO, Pocono Environmental EducationCenter, R.D.#1 Box 268, Dingmans Ferry, PA 18328

LESTER PALDY, State University of New York, Stony Brook, NY 11794

ROLAND PARE, Hunterdon Central High School, Route 31, Flemington, NJ 08822

JEAN W. PAXTON, In-Service Education Center, Jacksonville State University, Jacksonville, AL 36265

RICHARD P. PENNA, American Association of Colleges of Pharmacy, 4720 Montgomery Lane, Suite 602, Bethesda, MD 20814

DOROTHY PERRECA, American Statistical Association, 806 15th Street, N.W., Washington, DC 20005

PAUL PETERSON, The Brookings Institution, 1775 Massachusetts Avenue, N.W., Washington, DC 20036

G. WILL PFEIFFENBERGER, Educational Testing Service, Rosedale Road, Princeton, NJ 08541

EMIL J. PIEL, Department of Technology & Society, State University of New York/Stony Brook, Stony Brook, NY 11794

GEORGE PIMENTEL, Laboratory of Chemical Biodynamics, University of California, Berkeley, CA 94720

JOYCE J. PINKSTON, (Memphis City Schools), 2597 Avery Avenue, Memphis, TN 38112

HUGO PINTI, (Flint Michigan Community Schools), 925 So. Avon Street, Flint, MI 48502

JOSEPH C. PITT, Virginia Tech, Dept. of Philosophy, Blacksburg, VA 24061

THERESA A. PROENZA, 355 Rambling Road, Athens, GA 30606

CHARLES PUGLIA, National Science Foundation, 1800 G Street, N.W., Washington, DC 20550

JAMES V. QUAGLIANO, Virginia Commonwealth University, 1001 West Main Street, Department of Chemistry, Richmond, VA 23284

MANFRED J. RAETHER, University of Illinois, Physics Deparment, 1110 West Green Street, Urbana, IL 61801

J. THOMAS RATCHFORD, AAAS, 1333 H Street, N.W., Room 1007, Washington, DC 20005

MARY RAWSON, Metropolitan Pittsburgh Public Broadcasting, 4802 Fifth Avenue, Pittsburgh, PA 15217

MARTHA REDDEN, AAAS, 1333 H Street, N.W., Room 1007, Washington, DC 20005

DOUGLAS S. REYNOLDS, New York State Education Department, Room 302, Albany, NY 12234

SALLYE T. RICHARDS, Charlotte County Day School, 1440 Carmel Road, Charlotte, NC 28226

JOSEPH T. RICHERT, Elliott Pope Preparatory School, Box 338–26800 Saunders Meadow Road, Idyllwild, CA 92349

SALLY RIDE, Astronaut Office, Johnson Space Center, Houston, TX 77058

DONNA W. RIDENOUR, (Catalina Foothills Schools), 3752 Nugget Canyon, Tucson, AZ 85718

CONSTANCE A. RILEY, Jefferson Intermediate School, 800 Chapel Lane, Midland, MI 48640

BRUCE RINKER, The Langley School, 1411 Balls Hill Road, McLean, VA 22101

DIANNE Q. ROBINSON, Education/Special Education, Hampton University, Hampton, VA 23668

WILLIAM E. ROBINSON, P. O. Box 54496, Washington, DC 20032

CAROL L. ROGERS, AAAS, 1333 H Street, N.W. Room 804, Washington, DC 20005

JO ELLEN ROSEMAN, Johns Hopkins School of Continuing Studies, 34th & Charles Street, Baltimore, MD 21218

ROBERT ROSENBAUM, Wesleyan University, Middletown, CT 06457

ARNOLD E. ROSS, The Ohio State University, 231 W. 18th Street, Columbus, OH 43210

GORDON H. ROVELSTAD, American College of Dentists, 7315 Wisconsin Avenue, N.W., #352N, Bethesda, MD 20814

RUSTOM ROY, Materials Research Laboratory, The Pennsylvania State University, University Park, PA 16802

MARCIA RUDY, New York Hall of States, 47–01 111th Street, Corona, NY 11368

F. JAMES RUTHERFORD, AAAS, 1333 H Street, N.W., Room 1027, Washington, DC 20005

AMADO J. SANDOVAL, (Springbrook High School), 10350 Sixpence Circle, Columbia, MD 21043

DORIS SANDOVAL, 10350 Sixpence Circle, Columbia, MD 21043

JOHN F. SCHAFF, College of Education, University of Toledo, Toledo, OH 43606

LAWRENCE SCHARMANN, Indiana University of Pennsylvania, 7 Weyandt Hall, Indiana, PA 15705

DOROTHY SCHRIVER, Science Service Inc., 1719 N Street, N.W., Washington, DC 20036

ETHEL SCHULTZ, National Science Foundation, 1800 G Street, N.W., Washington, DC 20550

RICHARD A. SCRIBNER, AAAS, 1333 H Street, N.W. Room 1114, Washington, DC 20005

ALAN D. SEXTON, (Bucks County Intermediate Unit 22), Cross Keys Building, Rts. 611 & 313, Doylestown, PA 18901

BASSAM Z. SHAKHASHIRI, National Science Foundation, 1800 G Street, N.W., Room 516, Washington, DC 20550

EDWARD G. SHERBURNE, JR., Science Service Inc., 1719 N Street, N.W., Washington, DC 20036

GLENN K. SHERER, College of St. Thomas, Dept. of Biology, 2115 Summit Avenue, Saint Paul, MN 55105

EUGENE V. SHIRLEY, Herlong Elementary School Board, Drawer L, Herlong, CA 96113

DAVID K. SHORTESS, New Mexico Tech, Campus Station, Socorro, NM 87801

MAXINE SINGER, Chief, Laboratory of Biochemistry, National Cancer Institute, Bethesda, MD 20205

MICHAEL SKOLER, AAAS, 1333 H Street, N.W., Room 806, Washington, DC 20005

GERALD SKOOG, Chair, Secondary Education, Texas Tech University, P.O. #4560, Lubbock, TX 79409

LUCY SLINGER, Indiana University of Pennsylvania, 7 Weyandt Hall, Indiana, PA 15705

PATRICIA J. SMITH, Air Academy High School, USAF Academy, Colorado Springs, CO 80840

MARK SMULSON, Georgetown University, Washington, DC 20057

SUSAN P. SNYDER, Maryland State Department of Education, 200 W. Baltimore Street, Baltimore, MD 21201

LARRY G. SPEARS, University of Houston, 1 Main Street, Houston, TX 77002
GEORGE E. STANTON, Department of Biology, Columbus College, Columbus, GA 31993
LAURIE STOKELEY, (Claremont Graduate School), 322 W. 7th Street, Claremont, CA 91711
MARY JO STRAUSS, (Equity in Science Education), 4506 Cedell Place, Camp Springs, MD 20748
WILLIAM T. STUART, Rickover Science Institute, 7710 Old Springhouse Road, McLean, VA 22102
PATRICIA F. SULLIVAN, American Association of State Colleges and Universities, One Dupont Circle, Suite 700, Washington, DC 20036
GERALD SUMMERS, Division of Biological Sciences, University of Missouri, Columbia, MO 65211
IDA M. SUMMERS, Episcopal High School, Jacksonville, FL 32207
LEE J. SUMMERVILLE, Montgomery County Public Schools, 850 Hungerford Drive, Rockville, MD 20850
JINGYUAN SUN, Embassy of People's Republic of China, 2300 Connecticut Avenue, N.W., Washington, DC 20008
PAMELA SURKO, AT&T Bell Laboratories, 184 Liberty Corner Road, P.O. Box 4908, Warren, NJ 07060-0908
MARCIA P. SWARD, National Research Council, 1529 18th Street, N.W., Washington, DC 20036
KATHLEEN A. SWART, (University of Minnesota), 1960 Asbury Street N., Roseville, MN 55113
I. JOYCE SWARTNEY, (State University College at Buffalo), 1300 Elmwood Avenue, Buffalo, NY 14222
EARL M. SWEARINGEN, (Maine Township High School West), 1755 So. Wolf Road, Des Plaines, IL 60018
PATRICIA A. SWEENEY, Montgomery County Public Schools, MD
KATHLEEN SWEENEY-HAMMOND, The Maret School, 3000 Cathedral Avenue, N.W., Washington, DC 20005
HESSY L. TAFT, Educational Testing Service, Rosedale Road, Princeton, NJ 08540
ALBERT H. TEICH, AAAS, 1333 H Street, N.W., Room 1065, Washington, DC 20005
JEFFREY TERAMANI, AAAS, 1333 H Street, N.W., Room 807, Washington, DC 20005
PAUL ERIC THIESS, Joint Board of Science and Engineering Education
GEOFFREY P. THOMAS, University of Oxford, Department of External Studies, 1 Wellington Square, Oxford DX1 2JA England
CHARLES P. THOMPSON, (Kansas State University), 100 S. Delaware, Manhattan, KS 66502

ERTLE THOMPSON, University of Virginia, Ruffner Hall, 405 Emmet Street, Charlottesville, VA 22901

HECTOR TIMOURIAN, Science Education Center, Lawrence Livermore National Laboratory, Livermore, CA 94550

DOROTHY E. TOMBAUGH, (Euclid Public Schools), 971 Richmond Road, Lyndhurst, OH 44124

JOEL A. TURKEWITZ, The Field School, 2126 Wyoming Avenue, Washington, DC 20008

DEBBIE VAN RYN, Cornell University, Ithaca, NY 14850

JENNIFER W. VANCE, (Attorney), Suite 900, 1275 K Street, N.W., Washington, D. C. 20005

BONNIE VAN DORN, Association of Science/Technology Centers,, 1413 K Street, N.W., Washington, DC 20418

ANDREW J. VERDON, JR., American Geological Institute, 4220 King Street, Alexandria, VA 22302

LAURA VON BEHREN, National Research Council, 2101 Constitution Avenue, N.W., Washington, DC 20418

DAN B. WALKER, University of California, Los Angeles, AIP, 1332 Murphy Hall, Los Angeles, CA 90024

RICHARD C. WALLACE, JR., Pittsburgh Board of Public Education, 341 S. Bellefield Avenue, Pittsburgh, PA 15213

ROBERT T. WARD, Department of Physics, University of Northern Iowa, Cedar Falls, IA 50614

SYLVIA A. WARE, American Chemical Society, 1155 16th Street, N.W., Washington, DC 20036

JOHN WARING, (Research Writer), 1320-1 So. George Mason Drive, Arlington, VA 22204

PATRICIA WARREN, AAAS, 1333 H Street, N.W., Room 1031, Washington, DC 20005

FLETCHER WATSON, 24 Hastings Road, Belmont, MA 02178

SHIRLEY WATT, National Science Teachers Association, 1742 Connecticut Avenue, N.W., Washington, D. C. 20009

JEANNETTE WEDEL, AAAS, 1333 H Street, N.W., Room 1034, Washington, DC 20005

IRIS R. WEISS, Research Triangle Institute, P.O. Box 12194, Research Triangle Park, NC 27709

TERRY F. WERNER, Harris-Stowe State College, 3026 Laclede, St. Louis, MO 63103

J. EDMUND WHITE, Department of Chemistry, Southern Illinois University, Edwardsville, IL 62026

JUNE WIAZ, AAAS, 1333 H Street, N.W. Room 1060, Washington, DC 20005

PAUL R. WIDICK, West Chester University, Schmucker Science Center, West Chester, PA 19380

ALFRED B. WILLCOX, Mathematical Association of America, 1529 18th Street, N.W., Washington, DC 20036

EMILY NEEDHAM WILLIAMS, (Pressworks Publishing, Inc.), 3131 Briar Lane, Southlake, TX 76262

JACK M. WILSON, American Association of Physics Teachers, 5110 Roanoke Place, Suite 101, College Park, MD 20740

ARTHUR WISE, Rand Corporation, 2100 M Street, N.W. Washington, DC 20036

BARABARA L. WOLFE, The Center of Science & Industry, 280 E. Broad Street, Columbus, OH 43215

GLORIA WOODS, (The Ohio State University), 231 W. 18th Avenue, Columbus, Oh 43210

QIGUANG XIE, Embassy of People's Republic of China, 2300 Connecticut Avenue, N.W., Washington, DC 20036

ROBERT E. YAGER, University of Iowa, Science Education Center, 769 Van Street, Iowa City, IA 52242

BARBARA J. YENTZER, National Education Association, 1201 16th Street, N.W., Washington, DC 20036

BARBARA ZANGLER, (National Cathedral School), 1835 19th Street, N.W., Washington, DC 20009

ANN MARIE P. ZOLANDZ, Educational Testing Service, Rosedale Road, Princeton, NJ 08541

BERNARD ZUBROWSKI, 46 Oliver Street, Watertown, MA 02172

ANDREW A. ZUCKER, SRI International, 1611 North Kent Street, Arlington, VA 22209

C. Statistical Information on Science Teachers

Table A–1

General education: science taken.

	Teachers (N = 3,158)	*Arts and sciences (N = 2,083)*
Average total hours in science credits	11.6	12.2
Average total upper-level hours	.7	.9
Average percent science credits of total credits	8.2	9.1
Average total hours in science with laboratory (non-transfer)	6.0	7.0
Average total hours in biological sciences*	6.1	5.3
Average total hours in physics and chemistry*	1.8	3.3
Average total hours in other sciences (astronomy, earth science, etc.)*	3.6	3.5

*Average for individual disciplines do not add to total for all sciences combined because numbers of non-major graduates vary for individual disciplines.

From *An Analysis of Transcripts of Teachers and Arts and Sciences Graduates* (p. 26) by E.C. Galambos, L.M. Cornett, and H.D. Spitler, 1985, Atlanta, GA: Southern Regional Education Board. Reprinted by permission.

Table A–2

Number and percent of graduates by levels of mathematics taken.

	Teachers (N = 3,127)		Arts and sciences (N = 2,639)	
	Number	*Percent*	*Number*	*Percent*
1. No mathematics courses in college	220	7.0	280	11.0
2. Remedial, and no other mathematics course	105	3.0	74	3.0
3. Remedial mathematics and/or Level 2+ mathematics course(s)	338	11.0	313	12.0
4. "Teachers' mathematics" course(s)	771	25.0	14	.5
5. Remedial and/or "teachers' mathematics," and/or Level 2+ mathematics courses	1,334	43.0	339	13.0
6. Level 1* and/or upper-level mathematics	489	16.0	1,157	44.0

*Level 1: Prerequisite of 2 years high school algebra and 1 year geometry
+Level 2: Requires less preparation than for Level 1

The above categories are not additive because some graduates appear in more than one category. Each category refers to graduates who took only a combination of courses within that pattern, and no other courses. Categories 2 through 6 include credits earned at the participating institution only.

From *An Analysis of Transcripts of Teachers and Arts and Sciences Graduates* (p. 22) by E.C. Galambos, L.M. Cornett, and H.D. Spitler, 1985, Atlanta, GA: Southern Regional Education Board. Reprinted by permission.

Table A–3

General education credits taken by elementary and early childhood teachers (N = 1,251).

		Average hours	*Average percent of total credits (136.9 = total credits)*
Mathematics		7.7	5.7%
Science		12.1	8.8
Biology	6.2		
Chemistry/physics	1.3		
Other science	4.6		
English		12.2	8.9
Social science		23.6	17.3
History	6.9		
Political science	2.6		
Psychology	5.5		
Economics	.9		
Sociology	3.2		
Other social science	4.5		
Other liberal arts		13.7	10.0
Languages	1.8		
Fine arts	7.1		
Philosophy	.6		
Other humanities	4.2		
Total general education		69.3	50.7

From *An Analysis of Transcripts of Teachers and Arts and Sciences Graduates* (p. 37) by E.C. Galambos, L.M. Cornett, and H.D. Spitler, 1985, Atlanta, GA: Southern Regional Education Board. Reprinted by permission.

Table A–4

Percent of graduates completing at least nine hours in science disciplines.

	Teachers	*Arts and science*
Biological sciences	13%	12%
Other sciences (astronomy, earth science, etc.)	6	7
Chemistry and/or physics	4	11

From *An Analysis of Transcripts of Teachers and Arts and Sciences Graduates* (p. 28) by E.C. Galambos, L.M. Cornett, and H.D. Spitler, 1985, Atlanta, GA: Southern Regional Education Board. Reprinted by permission.

Table A–5

Percent of graduates not completing a single course in science disciplines.

	Teachers	*Arts and sciences*
Chemistry and/or physics	68%	54%
Other sciences (astronomy, earth science, etc.)	34	41
Biological sciences	11	25
Any science	*	1

*Less than 1 percent

From *An Analysis of Transcripts of Teachers and Arts and Sciences Graduates* (p. 28) by E.C. Galambos, L.M. Cornett, and H.D. Spitler, 1985, Atlanta, GA: Southern Regional Education Board. Reprinted by permission.

Table A–6

Hours of science taken and percent of credit in major.

	Teachers	*Arts and sciences*	
	Science education (N = 115)	*Biological sciences (N = 367)*	*Physical sciences (N = 310)*
Average hours			
Lower level	33.1	14.7	29.3
Upper level	16.2	24.6	26.5
Total*	49.3	39.3	55.8
Percent of at upper level	31.3%	62.1%	46.6%
Percent of total credit in major*	34.2%	28.7%	39.4%

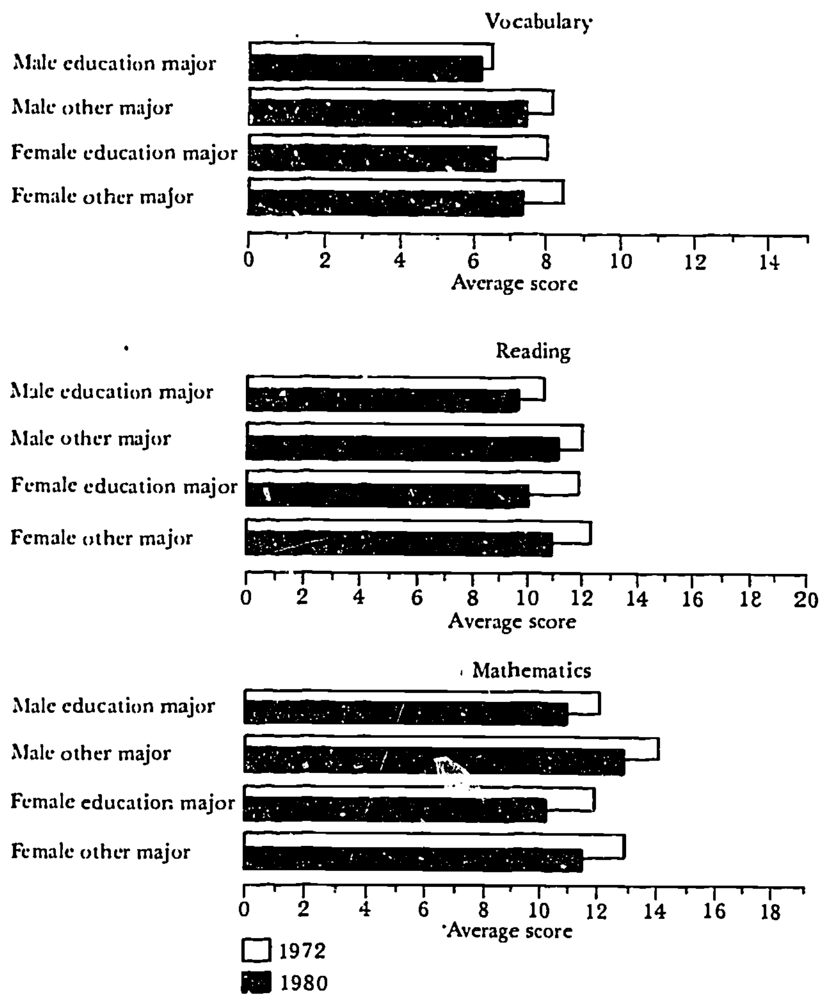
*Total credit in major for science education majors includes all credit taken in the biological sciences, physical sciences, and other physical and earth sciences.

Total credit in major for arts and sciences graduates includes the biological sciences for majors in biological science, and chemistry, physics, and other physical and earth sciences for physical science majors.

From *An Analysis of Transcripts of Teachers and Arts and Sciences Graduates* (p. 52) by E.C. Galambos, L.M. Cornett, and H.D. Spitler, 1985, Atlanta, GA: Southern Regional Education Board. Reprinted by permission.

Figure A–1

Vocabulary, reading, and mathematics test scores of high school seniors intending education majors compared with other intended majors.



From *The Condition of Education* (p. 223) by V. W. Plisko (Ed.), 1983, Washington, DC: National Center for Education Statistics.

Table A–7

Intended undergraduate fields of college-bound seniors by SAT scores, 1980–81.

Number responding	*906,195 Total*		
	SAT Verbal mean	*SAT Math mean*	*Selected SAT totals*
Arts and humanities	434	453	887
Architecture/environmental design	414	489	903
Art	403	421	824
English/literature	507	482	989
Foreign languages	474	477	951
Music	435	454	889
Philosophy and religion	463	481	944
Theater arts	439	436	875
Biological sciences and related areas	433	472	905
Agriculture	404	440	844
Biological sciences	471	504	975
Forestry/conservation	418	452	870
Health and medical	428	469	897
Business, commerce, and communications	406	446	852
Business and commerce	398	446	844
Communications	443	446	889
Physical sciences and related areas	443	527	970
Computer science/systems analysis	416	492	908
Engineering	446	534	980
Mathematics	456	572	1028
Physical sciences	498	558	1056
Social sciences and related areas	429	449	878
Education	391	418	809
Ethnic studies	381	395	776
Geography	422	474	896
History and cultures	482	472	954
Home economics	383	411	794
Library science	464	431	895
Military science	433	474	907
Psychology	433	447	880
Social sciences	456	474	930
Miscellaneous	420	459	879
Other	395	431	826
Trade and vocational	350	391	741
Undecided	440	480	920

Source: Admissions Testing Program of the College Board, *National Report, College Bound Seniors, 1981*, p.18.

From *Science and Engineering Education: Data and Information* (p. 127) by the National Science Foundation Office of Scientific & Engineering Personnel & Education, 1982, Washington, DC: National Science Foundation.

Table A-8 Trends in Graduate Record Examination mean verbal and quantitative test scores by field, 1970/71– 1977/78.

Prospective field of graduate study	*Aptitude type*	*1970/71*	*1971/72*	*1972/73*	*1973/74*	*1974/75*	*1975/76*	*1976/77*	*1977/78*
					Science fields				
Physical sciences	V	512	500	519	502	508	500	514	517
	Q	650	643	648	648	630	623	634	636
Mathematical sciences	V	517	495	510	513	506	520	513	504
	Q	675	673	676	675	661	673	666	669
Engineering	V	444	448	455	449	440	471	462	459
	Q	656	651	665	663	649	654	657	657
Life sciences	V	491	491	504	508	508	506	506	503
	Q	556	553	570	569	568	557	558	559
Basic social sciences	V	533	527	522	525	521	534	526	516
	Q	530	526	521	521	518	526	518	414
					Nonscience fields				
Health professions	V	500	502	509	508	502	513	507	498
	Q	496	501	508	507	513	530	527	517
Education	V	472	463	452	449	454	464	454	446
	Q	462	457	450	442	445	459	449	449
Arts and humanities	V	546	534	537	541	542	537	543	532
	Q	494	492	493	494	490	494	502	497
Applied social sciences	V	492	482	484	493	488	471	477	483
	Q	480	475	475	477	464	461	465	472
Other nonscience	V	496	490	501	498	496	507	498	486
	Q	498	500	502	495	498	509	510	504

*Note: V = verbal, Q = quantitative. Standard deviations cannot be computed for all years. For 1976/77, however, standard deviations ranged between 100 and 138.

Sources: Data for the years 1970/71 through 1974/75 are from a one-in-fifteen sample study of examinees of those years. See Robert F. Boldt, *Trends in Aptitude of Graduate Students in Science* (Princeton, N.J.: Educational Testing Service), p. 20. Mean scores for 1975/76 and 1976/77 were calculated from unpublished tabulations furnished by the Educational Testing Service, based on hte test results of a high proportion of all examinees of those years. Mean scores for 1977/78 are from *A Summary of Data Collected from Graduate Record Examination Test Takers During 1977/78, Data Summary Report No.3* (Princeton, N.J.: Educational Testing Service), February 1978, Tables 13, 14 and 42; pp. 42, 81-84 and 85-88.

Source: National Science Foundation, *Science Indicators – 1980.*

From *Science and Engineering Education: Data and Information* (p.133) by the National Science Foundation, 1982, Washington, DC: National Science Foundation.

Table A–9

Elementary teachers' perceptions of their qualifications to teach each subject.

	Percent of teachers			
Subject	*Not well qualified*	*Adequately qualified*	*Very well qualified*	*Missing*
Mathematics	4	46	49	1
Science	16	60	22	2
Social studies	6	54	39	1
Reading	3	32	63	2

Sample N = 1667

Source: Weiss, Iris R., *Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education*, p. 142.

From *Science and Engineering Education: Data and Information* (p. 101) by the National Science Foundation Office of Scientific & Engineering Personnel & Education, 1982, Washington, DC: National Science Foundation.

Table A–10

Percent of secondary teachers of each subject who feel inadequately qualified to teach one or more of their courses.

	Yes	*No*	*Unknown*
Mathematics			
7-9 (N = 550)		88	1
10-12 (N = 548)	[illegible]	95	0
Science			
7-9 (N = 535)	13	86	1
10-12 (N = 586)	13	82	3
Social studies			
7-9 (N = 453)	9	89	2
10-12 (N = 490)	16	81	3

Source: Weiss, Iris R., *Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education*, p. 144.

From *Science and Engineering Education: Data and Information* (p. 102) by the National Science Foundation Office of Scientific & Engineering Personnel & Education, 1982, Washington, DC: National Science Foundation.

Table A–11

Certification in field currently teaching of newly graduated[1] full-time elementary/secondary school teachers, May 1981.

Field currently teaching	*Number*	*Total*	*Certified or eligible for certification*: *In some field*	*In field currently teaching*	*In field other than currently teaching*	*Not eligible or don't know*
		Percentage distribution				
Total	79,000	100.0	93.8	77.9	15.9	6.2
Special education teachers, all	16,700	100.0	96.1	77.3	18.8	3.9
'Self-contained class' teachers	26,400	100.0	94.8	80.0	14.8	5.2
Specialty teachers	38,900	100.0	91.4	73.7	17.7	8.6
Arts and humanities	21,100	100.0	88.2	61.9	26.3	11.8
English language arts	10,200	100.0	84.6	50.6	34.0	15.5
Foreign languages and fine arts	11,000	100.0	91.6	72.3	19.2	8.4
Sciences and mathematics	15,500	100.0	86.9	43.7	43.2	13.1
Biological and physical sciences	7,900	100.0	88.3	45.4	43.0	11.7
Mathematics	7,500	100.0	85.4	42.0	43.4	14.6
Miscellaneous specialties[2]	30,700	100.0	90.4	57.2	33.2	9.6
Health and physical education	10,600	100.0	93.6	68.5	25.0	6.4
Social sciences/social studies	6,600	100.0	90.5	63.3	27.2	9.5
All other specialties[2]	13,600	100.0	87.9	45.4	42.4	12.1

[1] 1979-80 bachelor's degree recipients teaching elementary/secondary school full-time in May 1981.

[2] Does not include unclassified specialties because certification in field cannot be determined.

Note: Categories do not add to total because of multiple responses, i.e., teachers taught more than one field. Precision of the estimates may be calculated using the approximate coefficients of variation provided in the Data Sources in the Appendix.

Source: U.S. Department of Education, National Center for Education Statistics, Recent College Graduates Survey, 1981, unpublished tabulations (November 1982).

From *The Condition of Education* (p. 206) by V. W. Plisko (Ed.), 1983, Washington, DC: National Center for Education Statistics.

Table A–12

Certification of newly graduated teachers, 1979–1980.

Subject or field currently teaching	*Number*[a]	*Certified or eligible for certification* *Percent in some field*	*Percent in field currently teaching*	*Percent in field other than currently teaching*	*Percent not eligible or don't know*
Total	79,800	93.8	77.9	15.9	6.2
Special education teachers, all	16,700	96.1	77.3	18.8	3.9
"Self-contained class" teachers	26,400	94.8	80.0	14.8	5.2
English language arts	10,200	84.6	50.6	34.0	15.5
Foreign languages and fine arts	11,000	91.6	72.3	19.2	8.4
Biological and physical sciences	7,900	88.3	45.4	43.0	11.7
Mathematics	7,500	85.4	42.0	43.4	14.6
Health and physical education	10,600	93.6	68.5	25.0	6.4
Social sciences/social studies	6,600	90.5	63.3	27.2	9.5

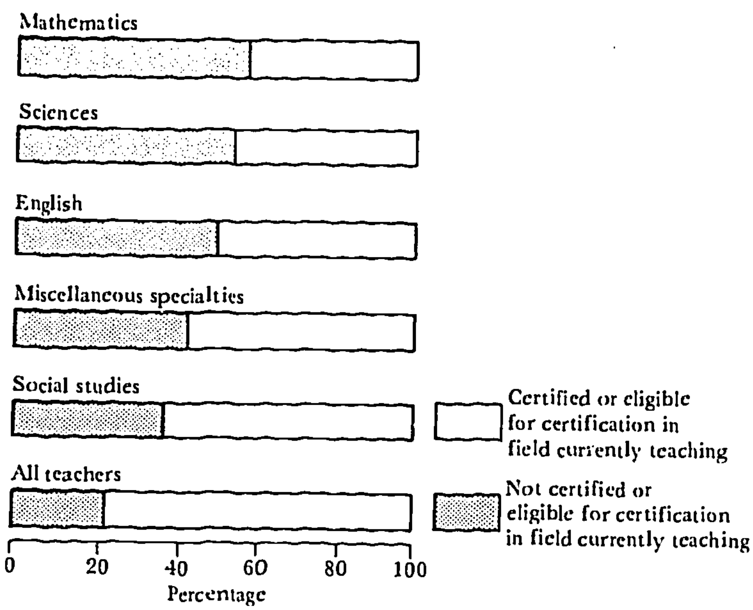
[a]1979-1980 bachelor's degree recipients teaching elementary or secondary school full time in May 1981.

Source: National Center for Education Statistics.

From *Indicators of Precollege Education in Science and Mathematics* (p. 53) by S.A. Raizen and L.V. Jones (Eds.), 1985, Washington, DC: National Academy Press.

Figure A–2

Qualifications of new teachers for the field they are currently teaching, 1981.



From *Beyond the Commission Reports: The Coming Crisis in Teaching* (p. 5) by L. Darling-Hammond, 1984, Santa Monica, CA: The Rand Corp. Reprinted by permission.

Table A–13

Percent of newly employed, but unqualified,* science and math teachers.

Census region	*1980-1981*	*1981-1982*
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
North East States	11	9
Atlantic States	40	46
South Atlantic States	48	50
Nationwide	45%	50%

*Uncertified

From testimony before the Subcommittee on HUD-Independent Agencies of the Senate Appropriations Committee (p. 4) by S.E. Klein, 24 May 1985.

Table A–14

Percent of emergency* science and math teachers hired in 1981–82.

Census region	*Percentage of emergency teachers hired*
Pacific States	84%
Mountain States	23%
West North Central States	43%
West South Central States	63%
East North Central States	46%
East South Central States	40%
Northeastern States	9%
Middle Atlantic States	43%
South Atlantic States	50%
Nationwide	50%

* Uncertified

From "The Teacher Crisis in Secondary School Science and Mathematics" by J.A. Shymansky and B.G. Aldridge, 1982, *Educational Leadership*, November 1982, p. 62. Reprinted with permission of the Association for Supervision and Curriculum Development.

Table A–15

Teacher certification requirements.

State	*Elementary*[a] Math	Science	*Secondary*[b] Math	Science	Test
Alabama	12 combined		12 combined		S
Alaska	U	U	U	U	
Arizona	12-30	12-30	30	30	S
Arkansas	6	9	21	24	NTE
California	U	U	U	U	S/NTE
Colorado	U	U	U	U	S
Connecticut	6	R	30	30	S
Delaware	U	U	30	39-45	S
D.C.	9	6	30	30	
Florida	6-12 combined		21	20	S
Georgia	U	U	45 qh	40-75 qh	S
Hawaii	U	U	major	major	
Idaho	6	8	20-45	20-45	
Illinois	5	7	24-32	24-32	
Indiana	R	R	24-52	24-52	
Iowa	U	R	30	30	
Kansas	12 combined		18	24	
Kentucky	12 combined		48	48	
Louisiana	6	6	20	20-32	S/NTE
Maine	U	U	18-50	18-50	
Maryland	6	12	24	36	
Massachusetts	U	U	36	36	
Michigan	U	U	30	30	
Minnesota	U	U	major	major	
Mississippi	15 combined		12 combined		NTE
Missouri	5	5	30	30	
Montana	U	U	20-40	20-40	
Nebraska	U	U	U	U	
Nevada	U	U	16-36	16-36	
New Hampshire	U	U	U	U	
New Jersey	R	R	24-30	24-30	
New Mexico	R	R	24-54	24-54	S/NTE
New York	R	R	24	36	NTE
N. Carolina	U	R	major	major	NTE
N. Dakota	U	R	U	U	
Ohio	6	8	20	20-60	
Oklahoma	R	R	28	36	S

(continued)

Table A–15 (continued)

State	*Elementary*[a] Math	Science	*Secondary*[b] Math	Science	Test
Oregon	12	U	21-42	45	
Pennsylvania	U	U	U	U	
Rhode Island	U	U	18	18	
S. Carolina	U	12	12-60	12-60	S/NTE
S. Dakota	2	4	major	major	
Tennessee	3 qh	12 qh	27 qh	24-48 qh	
Texas	U	U	U	U	NTE
Utah	U	U	16-46	16-46	S
Vermont	U	U	U	U	
Virginia	6	6	16-27	24	NTE
Washington	U	U	U	U	
W. Virginia	U	U	U	U	S
Wisconsin	U	U	22-34	22-34	
Wyoming	R	R	R	R	

Code:

U = credits in mathematics and/or science may be required for certification; these subjects, however, are not specifically mentioned.

R = credits in mathematics and/or science are required for certification; number of credits required is not indicated.

S = state-constructed test

NTE = National Teacher Examination

qh = quarter hour

Note: Unless otherwise noted, requirements are given in college semester hours required in mathematics and science for state certification for elementary school teachers and to teach mathematics or science in secondary school.

[a]Certification to teach: requirements given are for the lowest-level certificate. Many states require additional credit hours for certification as a specialist teacher in mathematics or science or for teaching in junior high school.

[b]Certification to teach mathematics or science. A wide spread in credit hours (e.g., 18-50 for Maine) generally means that the higher number includes courses in several sciences for certification to teach in all of them.

Source: Adapted from Woellner 1983) and Flakus-Mosqueda (1983).

From *Indicators of Precollege Education in Science and Mathematics* (pp. 62-63) by S.A. Raizen and L.V. Jones (Eds.), 1985, Washington, DC: National Academy Press.

Figure A–3

Teacher certification requirements: New York.

Requirements for Teaching Certificates

A. Elementary Teaching Certificate. Valid for teaching nursery, kindergarten, and grades 1-6. The provisional certificate is non-renewable and valid for five years. Requirements are: baccalaureate degree from an institution of higher education approved by the Commissioner; 24 semester hours of study in professional education, including at least six semester hours in the teaching of reading; and college supervised student teaching experience. The permanent certificate is valid for life and requires satisfaction of requirements for the provisional certificate; earned master's degree in an area functionally related to elementary education; and two years of elementary teaching experience.

B. Secondary Academic Teaching Certificates. Valid for teaching English, a foreign language, mathematics, science or social studies in grades 7-12. The provisional certificate is non-renewable and valid for five years. Requirements are: baccalaureate degree from an institution of higher education approved by the Commissioner; 12 semester hours of study in professional education; college supervised student teaching experience; and collegiate study in the area for which the certificate is being sought: (1) English–36 semester hours, (2) foreign language–24 semester hours in a specific foreign language, (3) mathematics–24 semester hours, including a year of study in calculus, (4) science–36 semester hours of study in science, including a minimum of 15 semester hours in the specific science area for which certification is sought (biology, chemistry, earth science or physics), and (5) social studies–36 semester hours in the social sciences. The permanent certificate is valid for life and the requirements are: satisfaction of requirements for the provisional certificate; earned master's degree in an area functionally related to the field of certification; and two years of experience as a secondary academic teacher.

C. Special Subject Teaching Certificates. Valid for arts, music, physical education, recreation and speech, in nursery, kindergarten and grades 1-12. The provisional certificate is non-renewable and valid for five years. The requirements are: baccalaureate degree from an institution of higher education approved by the Commissioner; 12 semester hours of study in professional education; college supervised student teaching experience; and 36 semester hours of study in the special subject area for which certification is requested. The requirements for the permanent certificate are: satisfaction of requirements for the provisional certificate; earned master's degree in an area functionally related to the field of certification; and two years of experience as a special subject teacher. This certificate is valid for life.

From *Manual on Certification and Preparation of Educational Personnel in the United States* (p. A-83) by R.A. Roth and R. Mastain (Eds.), 1984, Sacramento, CA: National Association of State Directors of Teacher Education and Certification. Copyright 1984 by the National Association of State Directors of Teacher Education and Certification. Reprinted by permission.

Figure A–4

Teacher certification requirements: California.

Requirements for Teaching Credentials

A. Multiple Subject (elementary/self-contained classroom) and Single Subject (secondary/departmentalized classroom).

1. Preliminary credential available only to candidates prepared outside of California: bachelor's or higher degree except in education; teacher preparation program, including student teaching; Basic Skills Examination (CBEST).
2. For the five-year preliminary* credential: all above, plus U.S. Constitution; teaching of reading; subject-matter competence (NTE or approved program); English language proficiency (CBEST).
3. For the five-year clear credential: all above, plus fifth year of study beyond bachelor's degree; health education (drug and alcohol abuse); special education (mainstreaming); and recommendation of a California college or university with a Commission-approved Multiple or Single Subject program.
4. For the life credential: two years of authorized full-time experience in California while holding the clear credential. Available until 9/1/85 only.

B. Teacher Trainee Certificate—an alternative route to certification: Legislation passed in 1983 provided an alternate route to certification. The teacher trainee certificate is available to individuals who meet the following requirements: a baccalaureate degree from a regionally accredited institution of higher education, with a major or minor in the subject to be taught; successful passage of the California Basic Educational Skills Test; successful passage of the Commission-approved subject matter examination(s) for the subject area(s) in which the teacher trainee is authorized to teach; verification by the governing board of the employing agency that fully credentialed teachers are not available and that the teacher trainee will be assisted and guided throughout the training period by a certificated employee who has been designated as a mentor teacher; Certificate of Clearance verifying the trainee's personal identification, and good moral character.

C. Specialist—Agriculture, Bilingual/Cross-Cultural Instruction, Early Childhood Education, Health Science, Mathematics, Reading, and Special Education, including Learning, Severely, Communication, Physically and Visually Handicapped and Gifted.

1. For the five-year clear credential: valid California teaching credential which requires a bachelor's degree and a professional preparation program including student teaching; fifth year of study beyond the bachelor's degree; professional preparation program in the specialist area; and recommendation of a California college or university with the specific Commission-approved specialist program.

   Candidates prepared outside of California may satisfy these requirements by verifying completion of a master's degree in the specialist area, including a practicum with school-age children, and eligibility for the equivalent credential authorization in the state where the program was completed.
2. For the life credential: two years of authorized full-time experience in California while holding the clear specialist and clear basic credentials. Available until September 1, 1985 only.

D. Designated Subject—Adult, Vocational and Special Subjects, including Driver Education and Driver Training, ROTC, Basic Military Drill, and Aviation Flight or Ground Instruction, full-time or part-time.

1. For the one-year preliminary** credential: five years of experience or the equivalent in the subject to be taught; high school diploma or equivalent; Basic Skills Examination (CBEST) for Adult academic subjects and Driver Education and Driver Training; recommendation of a Commission-approved Local Educational Agency (LEA) or Employing School District (ESD).
2. For the five-year preliminary ** credential: all the above requirements, plus U.S. Constitution (full-time credentials);
3. For the five-year clear** credentials: all above D. requirements, plus the preliminary credential; two years of successful full-time (or part-time) teaching as authorized by the preliminary credential; personalized preparation program of 9 semester units or 135 clock hours (4 semester units or 60 clock hours for part-time); health education (drug and alcohol abuse); and recommendation of a Commission-approved LEA or ESD.
4. For the life credential: two years of authorized full-time experience in California while holding the clear credential. Available until September 1, 1985 only. No life credential is available for the part-time credential.

*The Special Subject credentials require verifications specific to the subject to be taught.

**Only the clear credential can be renewed.

From *Manual on Certification and Preparation of Educational Personnel in the United States* (pp. A-15-16) by R.A. Roth and R. Mastain (Eds.), 1984, Sacramento, CA: National Association of State Directors of Teacher Education and Certification. Copyright 1984 by the National Association of State Directors of Teacher Education and Certification. Reprinted by permission.

Figure A–5

Instructional certification requirements: New Jersey.

State of New Jersey

DEPARTMENT OF EDUCATION
OFFICE OF
TEACHER CERTIFICATION & ACADEMIC CREDENTIALS
3535 QUAKERBRIDGE RD.—CN 503
TRENTON, NEW JERSEY 08625-0503

REQUIREMENTS FOR APPLICANTS FOR INSTRUCTIONAL CERTIFICATES IN NEW JERSEY

Effective September 1, 1985

The following requirements apply to applicants for instructional certificates in New Jersey.

1. Bachelor's degree from an accredited college or university.
2. Passing score in specialization area test of the National Teacher Examinations for secondary teachers and in the general knowledge test for elementary or nursery teachers. See information on test requirements for details and for exceptions.
3. Completion of 30 credits in a coherent sequence or 5 years of experience. This requirement refers to a major field of study or experience that corresponds to a specific teaching endorsement. Each year of related experience will be considered equivalent to six credits of the required 30 credits.
4. Completion of an approved teacher preparation program or the alternative route to certification. See information on the alternative route for details.

Note the following:

1. Applicants with evaluations completed prior to September 1, 1985 must complete requirements 1 and 2 above and requirements included in evaluations for issuance of a regular certificate in an instructional field. These applicants must complete all requirements by September 1990.
2. Applicants from out-of-state under any form of reciprocity in accordance with the Interstate Certification Compact will have met the content area requirement but must pass the required test for issuance of a regular instructional certificate in a specific field.
3. Out of state applicants not entitled to reciprocity shall meet requirements in 1, 2, 3 and 4 above.
4. All graduates of approved teacher preparation programs in New Jersey colleges must pass the required test but are not subject to the 30 credit requirement until Spring 1987.
5. After September 1, 1985, no instructional certificates will be issued in instructional fields based on transcript evaluation. Applicants must complete either a college approved teacher preparation program or a district training program through the alternative route to certification. Exceptions are bilingual/ESL education, special education and vocational education. See information on the alternative route to certification.
6. After September 1, 1985 no emergency certificates will be issued except in the following fields: bilingual/ESL education, special education and vocational education. Emergency certificates are issued upon approval of the county superintendent of schools.

Figure A–6

Letter to applicants concerning New Jersey's alternate route to teacher certification.

State of New Jersey
DEPARTMENT OF EDUCATION
OFFICE OF TEACHER CERTIFICATION AND ACADEMIC CREDENTIALS
3535 QUAKERBRIDGE ROAD
CN 503
TRENTON NEW JERSEY 08625-0503

Information for Prospective Applicants for
the Alternate Route to Certification

Dear Applicant:

This information is presented to you as an applicant who may be interested in the alternative route to certification. In September 1984 the State Board of Education revised certification regulations for applicants who have not completed education courses or student teaching to teach in the public schools. Through the alternate route to certification, such an individual may be hired as a salaried teacher and must then participate in a district training program for one year under a provisional certificate. Upon successful completion of the program the individual will be eligible for a regular certificate. This new plan allows districts to hire qualified but uncertified teachers even when certified teachers are available. District training programs will be available beginning September 1985. They will be offered in all instructional areas except:

Special Education Bilingual/ESL Education Vocational Education

All applicants for teaching positions, whether they complete college teacher education programs or the alternative route to certification will be required to pass a test of content knowledge; elementary teachers must pass a general knowledge test. We plan to begin the testing program in March, 1985.

It is our intention to develop a list of persons such as yourself who are interested in positions as provisional teachers and distribute the list to school districts in spring 1985. If you are interested in the alternative route to certification you should submit the following:

1. Completed information sheet (enclosed).
2. Credentials for evaluation in order to ascertain completion of the bachelor's degree and content area. Unofficial transcripts may be submitted for evaluation but no certificate will be issued with unofficial transcripts.
3. One page statement which lists all your occupational experiences, teaching experiences or other related experiences.
4. Money order or certified check for $30.00 payable to "Commissioner of Education" to cover evaluation and processing costs.

Your credentials and experience statements will be reviewed. You will be notified of the results of the review and information regarding test and administration. The above items should be sent to: Dr. Celeste M. Rorro, Director of Teacher Certification, New Jersey Department of Education, 3535 Quakerbridge Road-CN 503, Trenton, New Jersey 08625-0503.

I appreciate your prompt request and look forward to hearing from you. You may call this office at 609-292-4477 if you have questions regarding the Alternate Route to Certification.

Table A–16

Secondary school teachers assigned to mathematics and science classes in public schools in 1979–1980.

Field of Assignment	*Total*[a]	*Full time*
Mathematics	115,000	112,900
Science	104,700	101,000
Biology	25,000	24,300
Chemistry	11,400	10,500
Physics	6,700	5,700
General science	59,600	58,600
Other sciences	2,000	1,900

[a] Teachers assigned to more than one field were counted in the field in which they spent most of their time.

Source: National Center for Education Statistics.

From *Indicators of Precollege Education in Science and Mathematics* (p. 48) by S.A. Raizen and L.V. Jones (Eds.), 1985, Washington, DC: National Academy Press.

220

Table A–17

Alternative estimates of annual demand, supply, and shortage of high school mathematics and science teachers.

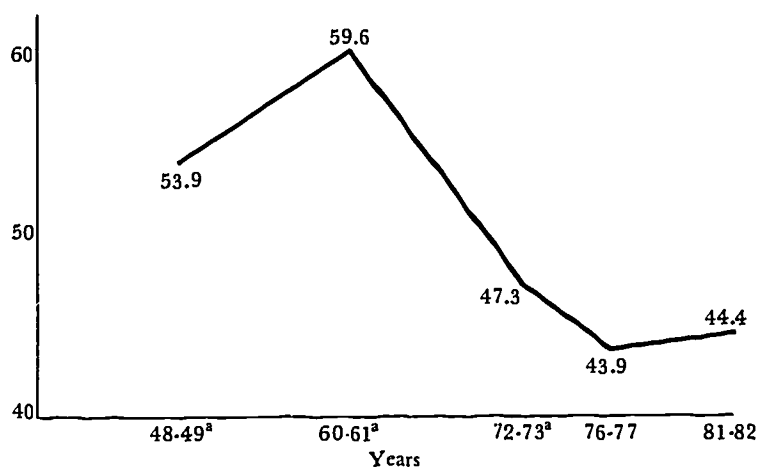
	Replacement assumptions					
	Zero		*2.5 percent – moderate*		*5 percent – high*	
	Math	*Science*	*Math*	*Science*	*Math*	*Science*
Unfilled positions	900	900	900	900	900	900
Resignations, retirements	6,000	5,500	6,000	5,500	6,000	5,500
Replacements	--	--	2,700	2,600	5,500	5,200
Total need	6,900	6,400	9,600	9,000	12,400	11,600
Less new entrants	3,200	3,600	3,200	3,600	3,200	3,600
New shortage	3,700	2,800	6,400	5,400	9,200	8,000

Note: The estimates are for the next 3 to 5 years. They do not take into account any possible changes in the function or structure of education. All the estimates assumed that decreased demand for teachers due to lower higher school enrollments will be balanced by increased demand due to higher requirements for high school graduation.

From *Indicators of Precollege Education in Science and Mathematics* (p. 60) by S.A. Raizen and L.V. Jones (Eds.), 1985, Washington, DC: National Academy Press.

Figure A–7

Percentage enrollment in eight science courses, grades 9–12.



[a]NCES data for public schools only.

From "How Many Are Enrolled in Science?" by W.W. Welch, L.J. Harris, and R.E. Anderson, 1984, *The Science Teacher*, December 1984, p. 18. Copyright 1984 by the National Science Teachers Association. Reprinted by permission.

Table A–18

Science enrollment, grades 7–9, 1981–1982.

	Course enrollment (thousands)			
Course	*Grade 7*	*Grade 8*	*Grade 9*	*Total*
General science	934	882	882	2707
Life science	1434	411	94	1939
Biology	115	55	363	533
Physical science	143	537	813	1493
Earth science	313	876	270	1459
Other	156	235	178	569
Total	3104	2996	2600	8700
Grade enrollment	3445	3341	3465	10151
	Percentage of grade level			
General science	27	26	25	27
Life science	42	12	3	19
Biology	3	2	10	5
Physical science	4	16	23	15
Earth science	9	26	8	14
Other	5	7	5	6
Total	90	89	74	86

From "How Many Are Enrolled in Science?" by W.W. Welch, L.J. Harris, and R.E. Anderson, 1984, *The Science Teacher*, December 1984, p. 16. Copyright 1984 by the National Science Teachers Association. Reprinted by permission.

222

Table A–19

Science enrollment, grades 10–12, 1981–1982.

Course	Course enrollment (thousands) Grade 10	Grade 11	Grade 12	Total
General science	141	51	33	224
Biology	1953	201	107	2261
Chemistry	165	740	227	1132
Physics	11	130	363	504
Earth science	63	38	17	118
Physical science	120	66	34	220
Other	312	320	273	905
Total	2765	1546	1054	5356
Grade enrollment	3366	3186	3083	9623
		Percentage of grade level		
General science	4	2	1	2
Biology	58	6	3	23
Chemistry	5	23	7	12
Physics	0	4	12	5
Earth science	2	1	1	1
Physical science	9	10	9	9
Other	9	10	9	9
Total	82	48	34	56[a]

[a]Because of rounding errors, column sums may not equal the total.

From "How Many Are Enrolled in Science?" by W.W. Welch, L.J. Harris, and R.E. Anderson, 1984, *The Science Teacher*, December 1984, p. 16. Copyright 1984 by the National Science Teachers Association. Reprinted by permission.

Table A–20

Changes in science enrollment, grades 7–9, 1977–1982.

Course	1976-1977 N (1000s)	Ratio[a]	1981-1982 N (1000s)	Ratio	Change N (1000s)	Ratio
General science	3655	29.5	2707	26.7	− 948	−2.8
Life science	1902	15.4	1939	19.1	+ 37	+3.7
Earth science	1721	13.9	1459	14.4	− 262	+0.5
Physical science	1955	15.8	1493	14.7	− 462	−1.1
Biology	724	5.8	533	5.3	− 191	−0.5
Integrated science	265	2.1	246	2.4	− 19	+0.3
Environmnetal science	114	0.9	115	1.1	+ 1	+0.2
Other	367	3.0	208	2.0	− 159	−1.0
Total	10703	86.4	8700	85.7	−2003	−0.7

[a]Ratio is defined here as the subject enrollment divided by the grade 7-9 enrollment. In 1976-1977, total enrollment was 12,200,000 (NCES). In 1981-1982, it was 10,600,000 (NCES).

From "How Many Are Enrolled in Science?" by W.W. Welch, L.J. Harris, and R.E. Anderson, 1984, *The Science Teacher*, December 1984, p. 19. Copyright 1984 by the National Science Teachers Association. Reprinted by permission.

Table A–21

Changes in science enrollment, grades 10–12, 1977–1982.

Course	1976-1977 N (1000s)	1976-1977 Ratio[a]	1981-1982 N (1000s)	1981-1982 Ratio[a]	Change N (1000s)	Change Ratio
General science	164	4.3	224	7.0	+ 60	+2.7
Biology	2675	63.0[b]	2261	67.2[b]	–414	+4.2
Chemistry	1121	29.3[b]	1132	35.5[b]	+ 11	+6.2
Physics	487	14.6[b]	504	16.3[b]	+ 17	+1.7
Life science	135	3.6	199	6.2	+ 64	+2.6
Environmental science	206	5.4	151	4.7	– 53	–0.7
Physical science	260	6.8	220	6.8	– 40	0.0
Earth science	167	4.4	118	3.7	– 49	–0.7
Integrated science	37	1.0	19	0.6	– 18	–0.4
Astronomy	23	0.6	26	0.8	+ 3	+0.2
Anatomy/physiology	127	3.3	90	2.8	– 37	–0.5
Oceanography	24	0.6	40	1.2	+ 15	+0.6
Horticulture	11	0.3	8	0.2	– 3	–0.1
Geology	42	1.1	58	1.8	+ 16	+0.7
Zoology	53	1.4	28	0.9	– 25	–0.5
Botany	35	0.9	10	0.3	– 25	–0.6
Advanced biology	129	3.9[b]	90	2.8[b]	– 39	–1.1
Advanced chemistry	27	0.7[b]	22	0.7[b]	– 5	0.0
Advanced physics	9	0.2[b]	7	0.2[b]	– 2	0.0
Other	153	4.0	157	4.9	+ 4	+0.9
Total	5885	51.6[c]	5365	55.7[c]	–520	+4.1

[a]Ratio is defined as the total enrollment divided by the average enrollment in grades 10-12. In 1976-1977 this was 3,802,000; in 1981-1982 it was 3,212,000.

[b]The divisor for biology, chemistry, physics, and advanced placement is the grade enrollment for the grade where the course usually is taught.

[c]Divisor is the sum of grades 10-12 enrollment.

From "How Many Are Enrolled in Science?" by W.W. Welch, L.J. Harris, and R.E. Anderson, 1984, *The Science Teacher*, December 1984, p. 19. Copyright 1984 by the National Science Teachers Association. Reprinted by permission.

Table A–22

Regional science enrollment, grades 7–9, 1981–1982.

	Percentage of grade enrolled in science courses											
Subject	*Grade 7*				*Grade 8*				*Grade 9*			
	NE	*SE*	*C*	*W*	*NE*	*SE*	*C*	*W*	*NE*	*SE*	*C*	*W*
General science	34	29	39	9	36	17	35	16	34	28	25	17
Life science	37	46	31	53	8	10	18	11	3	1	4	3
Biology	6	1	4	2	1	4	1	1	14	9	11	7
Physical science	7	0	7	2	21	13	14	17	22	33	12	27
Earth science	8	16	7	7	19	39	16	34	17	3	7	4
Other	9	5	3	1	10	3	5	3	4	0	11	2
Total	101	97	91	74	95	86	89	82	94	74	80	60

Percentage of grades 7-9 enrolled in science
Northeast: 97 Southeast: 86 Central: 87 West: 72
Nation: 86

From "How Many Are Enrolled in Science?" by W.W. Welch, L.J. Harris, and R.E. Anderson, 1984, *The Science Teacher*, December 1984, p. 17. Copyright 1984 by the National Science Teachers Association. Reprinted by permission.

Table A–23

Regional science enrollment, grades 10–12, 1981–1982.

	Percentage of grade enrolled in science courses											
	Grade 10				*Grade 11*				*Grade 12*			
Subject	*NE*	*SE*	*C*	*W*	*NE*	*SE*	*C*	*W*	*NE*	*SE*	*C*	*W*
Biology	63	59	52	59	8	7	4	7	5	3	3	3
Chemistry	9	4	4	3	35	19	20	19	6	6	10	7
Physics	0	0	1	0	6	3	4	3	19	10	11	7
Advanced	0	1	0	0	1	1	1	2	3	2	2	2
Other	18	16	15	22	15	10	14	14	12	0	7	9
Total	90	80	72	84	65	40	43	45	45	21	33	28

Percentage of grades 10-12 enrolled in science
Northeast: 67 Southeast: 47 Central: 49 West: 52
Nation: 56

From "How Many Are Enrolled in Science?" by W.W. Welch, L.J. Harris, and R.E. Anderson, 1984, *The Science Teacher*, December 1984, p. 18. Copyright 1984 by the National Science Teachers Association. Reprinted by permission.

Table A–24

Minimum high school graduation requirements in mathematics and science, as of August 198[illegible].

State	Years of instruction: Mathematics	Years of instruction: Science	Total credits[a] required	Requirements increased since 1980: Mathematics	Requirements increased since 1980: Science	Statewide mandate for testing[b]
Alabama	2	1	20	x	+	x
Alaska	2	2	21	x	x	x
Arizona	2	2	20	x	x	x
Arkansas	2-3 (5 total)	2-3	20	x	x	x
California	2	2	13	x	x	x
Colorado	Local determination					
Connecticut	3	2	20	x	x	x
Delaware	2	2	19	x	x	x
D.C.	2	2	20.5	x	x	x
Florida	3	3	24	x	x	x
Georgia	2	2	21	x	x	x
Hawaii	2	2	20			x
Idaho	2	2	20	x	x	x
Illinois	2	1	16	x	x	x
Indiana	2	2	19.5	x	x	x
Iowa						
Kansas	2	2	20	x	x	x
Kentucky	3	2	20	x	x	x
Louisiana[c]	3	3	23	x	x	x
Maine	Local determination		16			x
Maryland	2	2	20	+	+	x
Massachusetts	Local determination					
Michigan	Local determination					x
Minnesota	1	1	20	x	x	x
Mississippi	1	1	16	x	x	x
Missouri	2	2	22	x	x	x
Montana	2	1	20			x
Nebraska	Local determination		20			x
Nevada	2	1	20	x		x
New Hampshire[c]	2	2	19.75	x	x	x
New Jersey	2	1	18.5	+	+	x
New Mexico	2	2	21	x	x	x
New York	1	1	16	+	+	x
N. Carolina	2	2	20	+	+	x
N. Dakota	2	2	17	x		
Ohio	2	1	18	x		
Oklahoma	2	2	20	x	x	
Oregon	2	2	22	x	x	x
Pennsylvania	3	3	21	x	x	x
Rhode Island	1	1	16	+	+	x
S. Carolina	3	2	20	x	x	x
S. Dakota[c]	2	2	20	x	x	
Tennessee	2	2	20	x	x	x
Texas	3	2	21	x	x	x
Utah[c]	2	2	24	x	x	x

(continued)

Table A–24 (continued)

State	Years of instruction: Mathematics	Years of instruction: Science	Total credits[a] required	Requirements increased since 1980: Mathematics	Requirements increased since 1980: Science	Statewide mandate for testing[b]
Vermont	3	3	15.5	x	x	x
Virginia	2-3 (5 total)	2-3	18	x	x	x
Washington	2	2	16	x	x	x
W. Virginia	2	1	20		+	+
Wisconsin[c]	2	2	13.5	x	x	x
Wyoming	Local determination		18			

Code: x = requirements increased since 1980.
+ = additional requirements under study.

[a]A credit is defined as a year of instruction. Some of the listed requirements are to be phased in over the next 3 to 5 years.

[b]May include competency-based tests required for high school graduation, testing at selected grade levels, use of standardized tests, or tests developed by the state or districts. Proficiency tests in basic mathematical skills usually are included; tests in science are less frequent (see Table A3, Appendix).

[c]States requiring 0.5-1 year of computer science or computer literacy in addition to mathematics and science requirements. Several more states are evaluating computer literacy requirements.

Source: Adapted from Parrish (1980), Dougherty (1983), U.S. Department of Education (1984), Education Commission of the States (1984), and Council of Chief State School Officers (1984).

From *Indicators of Precollege Education in Science and Mathematics* (pp. 56-59) by S.A. Raizen and L.V. Jones (Eds.), 1985, Washington, DC: National Academy Press.

Table A–25

Percent minority enrollment and teachers in Montgomery County, Maryland.

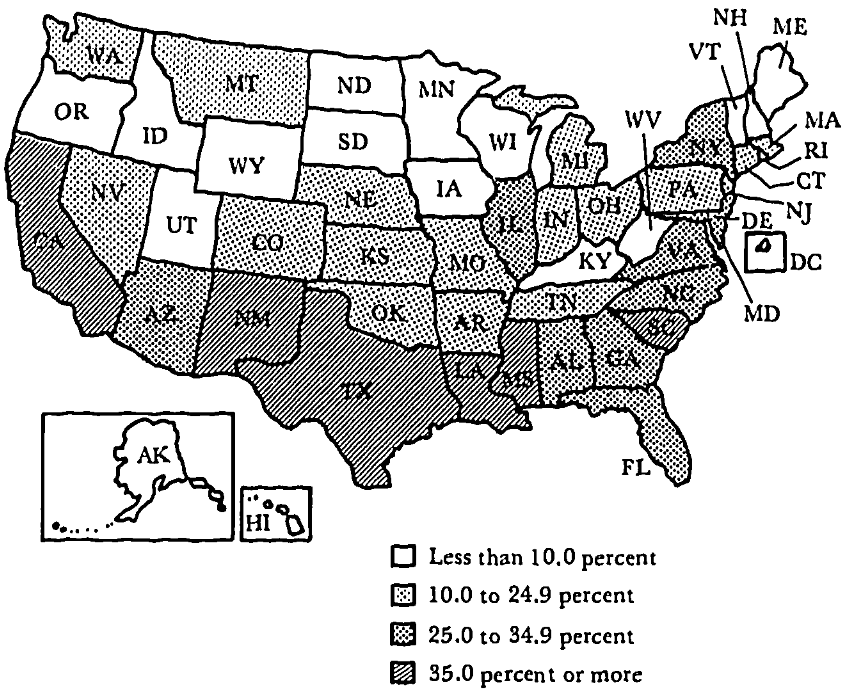
Students	*Fall 1981*	*Fall 1982*	*Fall 1983*	*Fall 1984*	*Fall 1985*
White	76.2%	74.6%	73.0%	71.0%	70.2%
Black	12.7%	13.3%	14.0%	14.7%	14.7%
Asian	6.6%	7.3%	8.0%	8.8%	9.3%
Hispanic	4.3%	4.6%	4.8%	5.3%	5.6%
American Indian	0.2%	0.2%	0.2%	0.2%	0.2%
Teachers	*June 1981*	*June 1982*	*June 1983*	*June 1984*	*Fall 1985*
White	89.0%	88.8%	88.5%	88.2%	88.6%
Black	9.4%	9.6%	9.6%	9.8%	9.4%
Asian	0.6%	0.6%	0.7%	0.7%	0.8%
Hispanic	1.0%	1.0%	1.2%	1.3%	1.2%

Source: Montgomery County Public Schools

From "Schools Look for Minority Instructors" by Chris Spolar, 1985, in *The Washington Post*, 14 September 1985.

Figure A–8

Minority enrollment as percent of public elementary/secondary school enrollment, by state.



Percent minority enrollment in public elementary secondary schools was generally greatest in the Southern and Southwestern States and in California. The percent black enrollment was highest in the Southern States while the percent Hispanic enrollment was highest in New Mexico, Texas, California, and Arizona.

From *The Condition of Education* (p. 23) by V.W. Plisko (Ed.), 1983, Washington, DC: National Center for Education Statistics.

Table A–26

Estimated supply of secondary science and mathematics teachers, 1980 and 1981.

Response	*Biology* 1980	*Biology* 1981	*Chemistry* 1980	*Chemistry* 1981	*Physics* 1980	*Physics* 1981	*General science* 1980	*General science* 1981	*Earth science* 1980	*Earth science* 1981	*Math* 1980	*Math* 1981
1	6	6	3	0	3	0	4	4	3	1	3	0
2	13	10	2	2	0	1	5	5	1	1	1	1
3	24	26	13	8	6	4	27	23	14	13	10	3
4	4	4	21	28	19	15	11	9	23	22	16	25
5	2	1	10	9	21	27	2	5	8	10	16	18
NR	4	6	4	6	4	6	4	7	4	6	7	6

Responses: 1 = Surplus; 2 = Slight surplus; 3 = Adequate supply; 4 = Shortage; 4 = Critical shortage; NR = No response.

Source: Trever G. Howe and Jack A. Gerlovich, *National Study of the Estimated Supply and Demand of Secondary Science and Mathematics Teachers.* November, 1981.

From *Science and Engineering Education: Data and Information* (p. 7) by the National Science Foundation Office of Scientific & Engineering Personnel & Education, 1982, Washington, DC: National Science Foundation.

Table A–27

Estimated supply of secondary biology, chemistry, physics, general science, earth science, and mathematics teachers by state, 1980–81.

State	*Biology* 1980	*Biology* 1981	*Chemistry* 1980	*Chemistry* 1981	*Physics* 1980	*Physics* 1981	*General science* 1980	*General science* 1981	*Earth science* 1980	*Earth science* 1981	*Math* 1980	*Math* 1981
Alabama	2	2	3	3.5	5	5	3	3	4	4	NR	4
Alaska	1	2	1	2	1	2	1	2	1	2	1	2
Arizona	NR	3	NR	4	NR	5	NR	5	NR	3	NR	4
Arkansas	3	3	4	4	4	4	3	3	3	3	4	4
California	2	3	2	4	4	4	3	3	4	4	2	4
Colorado	3	3	3.5	4	3.5	4	3.5	4	3.5	4	3.5	4
Connecticut	3	3	3	4	4	5	3	4	3	4	4	5
Delaware	3	1	3	3	3	4	3	1	3	1	3	4
District of Columbia	3	3	3	3	4	4	2	3	3	3	4	5
Florida	3	3	5	5	5	5	4	4	5	5	4	4
Georgia	1	2.5	1	3.5	1	4	1	5	1	4	1	5
Hawaii	2	3	4	4	4	5	3	3	4	4	3	4
Idaho	1	1	4	4	4	4	3	3	4	3	4	4
Illinois	3	3	5	5	5	5	4	4	4	4	5	5
Indiana	5	5	5	5	5	5	5	5	5	5	5	5
Iowa	2	2	5	4	5	5	3	3	4	4	5	5
Kansas	2	3	4	4	4	4	4	3	4	3	4	5
Kentucky	3	3	4	4	5	5	3	3	4	4	5	5
Louisiana	3	3	4	4	5	5	3	3	4	4	4	4
Maine	3	3	3.5	5	3.5	5	3.5	3	3.5	3	4	4
Maryland	3	2	4	4	4	4	4	4	4	4	4	5
Massachusetts	1	NR	1	NR	1	NR	1	NR	1	NR	1	NR
Michigan	3	NR	4	NR	4	NR	3	NR	3	NR	4	NR

(continued)

Table A–27 (continued)

State	*Biology*		*Chemistry*		*Physics*		*General science*		*Earth science*		*Math*	
	1980	*1981*	*1980*	*1981*	*1980*	*1981*	*1980*	*1981*	*1980*	*1981*	*1980*	*1981*
Minnesota	2	2	3	3	4	4	3	3	3	3	NR	4
Mississippi	1	1	2	2	4	4	1	1	4	4	NR	3
Missouri	4	4	5	5	5	5	4	4	4	4	5	5
Montana	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Nebraska	3	3	4	4	4	4	3	3	4	3	3	4
Nevada	3	3	4	4	5	5	3	3	3	3	4	4
New Hampshire	2	3	5	5	5	5	4	4	5	5	5	5
New Jersey	3	NR	3.5	NR	4	NR	3	NR	3	NR	3	NR
New Mexico	2	NR	3	NR	4	NR	2	NR	3	NR	4	NR
New York	3	3	4	4	5	5	3	3	4	4	5	5
N. Carolina	4	2	5	4	5	5	4	3	4	5	5	5
N. Dakota	3	3	4	4	4	4	4	NR	4	4	4	4
Ohio	2	3	4	4	5	5	3	3	2	3	3	3
Oklahoma	2	3	4	4	5	5	2	2	5	5	5	4
Oregon	3	2	3	4	3	5	3	3	3	4	5	4
Pennsylvania	2	1	4	4	5	5	2	1	4	5	5	5
Rhode Island	NR	3	NR	3	NR	3	NR	3	NR	3	NR	4
S. Carolina	4	4	5	5	5	5	4	3	5	5	5	5
S. Dakota	3	3.5	4	4	5	5	3	3.5	3	3.5	3	5
Tennessee	3	2.5	3.5	4	3.5	4	3	2	4	4	3.5	4
Texas	2	1	3	3	3	3	4	5	5	5	5	5
Utah	3	3	4	4	4	4	3	3	4	4	4	5
Vermont	4	4	4	5	5	5	3	4	3	4	3	4
Virginia	1	1	3	4	4	3	2	1	5	4	4	4
Washington	3	NR	4	NR	4	NR	3	NR	4	NR	3.5	NR
W. Virginia	3	3	5	4	5	5	4	4	4	4	5	4
Wisconsin	2	3	4	4	5	5	4	3	4	4	5	4
Wyoming	3	3	4	3	4	3	3	2	4	3	4	4
American Samoa	5	4	5	5	5	5	5	5	5	5	5	4
Puerto Rico	NR	2	NR	4	NR	5	NR	2	NR	5	NR	3

Response: 1 = Surplus; 2 = Slight surplus; 3 = Adequate supply; 4 = Shortage; 5 = Critical shortage; NR = No response

Source; Trever G. Howe and Jack A. Gerlovich, *National Study of the Estimated Supply and Demand of Secondary Science and Mathematics Teachers.* November, 1981.

From *Science and Engineering Education: Data and Information* (p. 7) by the National Science Foundation Office of Scientific & Engineering Personnel & Education, 1982, Washington, DC: National Science Foundation.

Table A–28

Supply of individuals with mathematics education and science education degrees granted, 1971–72 to 1979–80.

I. Bachelors Degrees requiring 4 or 5 years

	Total	*Mathematics education*			*Science education*		
	All fields	*Total*	*Male*	*Female*	*Total*	*Male*	*Female*
1971-72	887,272	2,425	1,144	1,281	1,064	[illegible]	[illegible]
1973-74	945,776	2,037	921	1,116	941	542	[illegible]
1975-76	934,443	1,442	594	848	792	451	341
1977-78	921,204	1,048	439	609	755	416	339
1979-80	929,417	762	310	452	672	309	363

II. Masters Degree

	Total	*Mathematics education*			*Science education*		
	all fields	*Total*	*Male*	*Female*	*Total*	*Male*	*Female*
1971-72	251,633	764	413	351	758	446	312
1973-74	277,033	828	447	381	904	604	300
1975-76	313,001	746	335	411	737	421	316
1977-78	311,620	598	230	368	775	406	369
1979-80	298,081	512	211	301	591	328	263

Source: Digest of Education Statistics (various editions), NCES.

From *Science and Engineering Education: Data and Information* (p. 8) by the National Science Foundation Office of Scientific & Engineering Personnel & Education, 1982, Washington, DC: National Science Foundation.

Table A–29

Bachelor's degrees conferred in selected areas of education, by level and specialty, 1971–81.

Field of Bachelor's Degree	*1970-1971*	*1980-1981*	*Percent change*
Education, total	176,614	108,309	–38.7
Elementary education, general	90,432	38,524	–57.4
Special education, all specialties	8,360	13,950	66.9
Art education	5,661	2,392	–57.7
Music education	7,264	5,332	–26.6
Mathematics education	2,217	798	–64.0
Science education	891	597	–33.0
Physical education	24,732	19,095	–22.8
Business, commerce, and distributive education	8,550	3,405	–60.2
Industrial arts, vocational and technical education	7,071	5,772	–18.4
Home economics education	6,449	1,767	–72.6

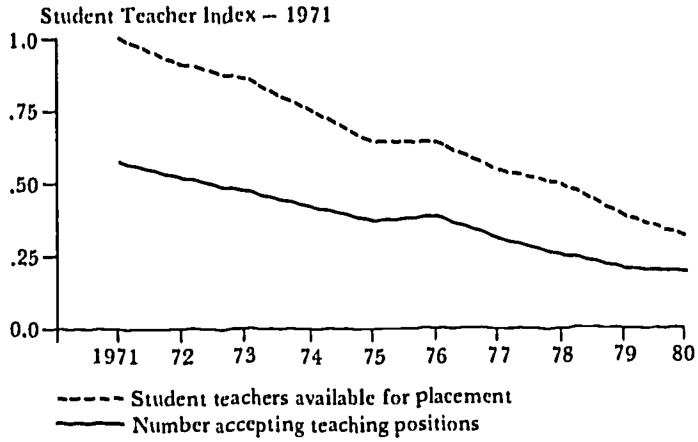
Note: Numbers do not include individuals certified to teach a subject but graduating with a different type of major.

Source: National Center for Education Statistics.

From *Indicators of Precollege Education in Science and Mathematics* (p. 51) by S.A. Raizen and L.V. Jones (Eds.), 1985, Washington, DC: National Academy Press.

Figure A–9

Student teacher supply index (science), based on 1971 supply.



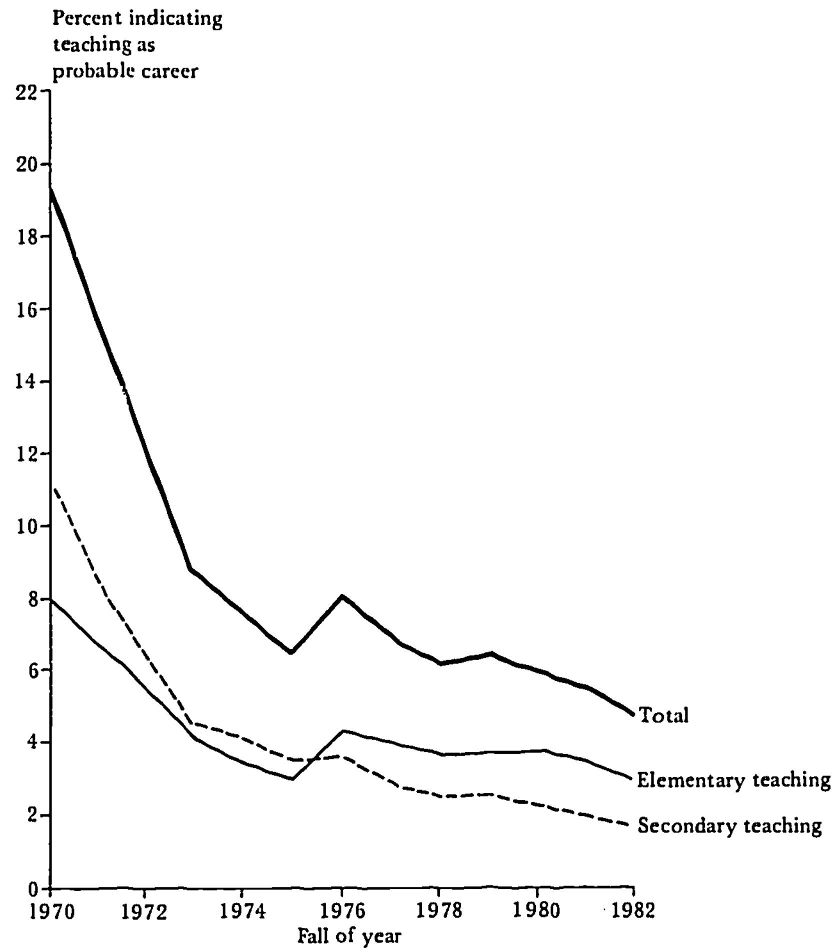
Based on National Science Teachers Association survey of college and university placement officers. Conducted by J. A. Shymansky, The University of Iowa, 1982.

From "The Teacher Crisis in Secondary School Science and Mathematics" by J.A. Shymansky and B.G. Aldridge, 1982, *Educational Leadership*, November 1982, p. 62. Reprinted with permission of the Association for Supervision and Curriculum Development.

232

Figure A–10

College freshmen indicating teaching as probable career.



From *The Condition of Education* (p. 219) by V. W. Plisko (Ed.), 1983, Washington, DC: National Center for Education Statistics.

Table A–30

Earned degrees in mathematics and science education, by level of degree and sex, 1979–80.

	Bachelor's degrees			*Master's degrees*			*Doctor's degrees*		
	Total	*Men*	*Women*	*Total*	*Men*	*Women*	*Total*	*Men*	*Women*
Mathematics education	832	338	494	517	212	305	38	23	15
Science education	725	327	398	591	328	263	73	50	23

Source: U.S. Department of Health, Education and Welfare, National Center of Education Statistics. *Earned Degrees Conferred, (1979-80). p. 21.*

From *Science and Engineering Education: Data and Information* (p. 157) by the National Science Foundation Office of Scientific & Engineering Personnel & Education, 1982, Washington, DC: National Science Foundation.

Table A–31

Percent of male and female teachers of science, mathematics, and social studies, by grade range.

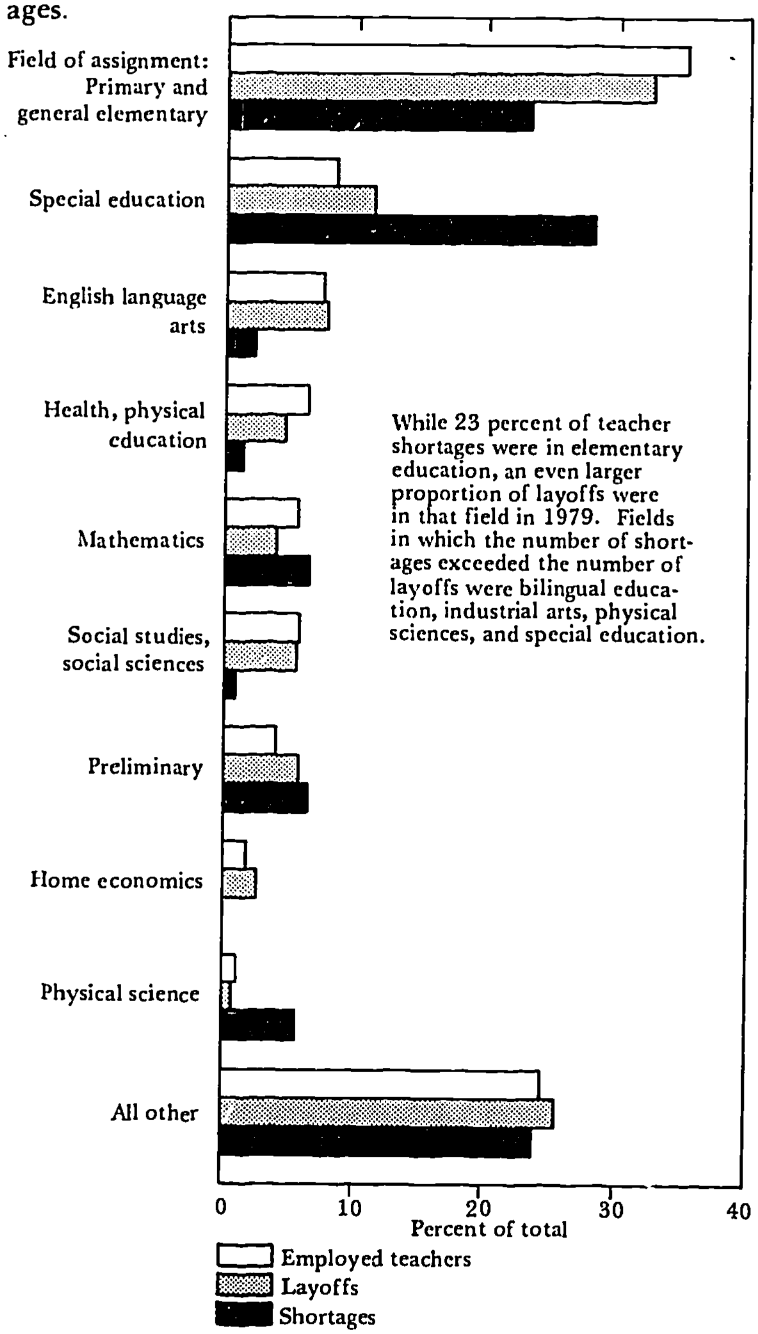
Grade range	*Mathematics*			*Science*			*Social studies*			*Total*		
	M	*F*	*Unknown*	*M*	*F*	*Unknown*	*M*	*F*	*Unknown*	*M*	*F*	*Unknown*
K-3 (N = 838)	6	94	0	2	98	0	3	96	1	4	96	0
4-6 (N = 829)	21	76	2	33	67	0	19	79	1	25	74	1
7-9 (N = 1538)	54	46	0	62	38	0	62	38	0	59	41	0
10-12 (N = 1624)	68	32	0	74	24	2	75	24	1	73	26	1
Sample N	1672			1679			1478			4829		

Source: Weiss, Iris R., *Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education*, p. 141.

From *Science and Engineering Education: Data and Information* (p. 4) by the National Science Foundation Office of Scientific & Engineering Personnel & Education, 1982, Washington, DC: National Science Foundation.

Figure A–11

Employed teachers and teacher layoffs and shortages by field as percent of total employed teachers and teacher layoffs and shortages.

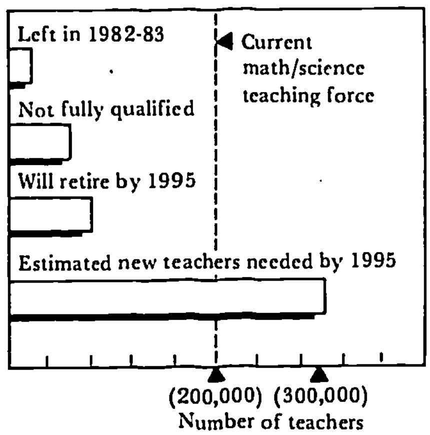


Source: The Condition of Education, NCES, 1982, p. 101.

From *Science and Engineering Education: Data and Information* (p. 5) by the National Science Foundation Office of Scientific & Engineering Personnel & Education, 1982, Washington, DC: National Science Foundation.

Figure A–12

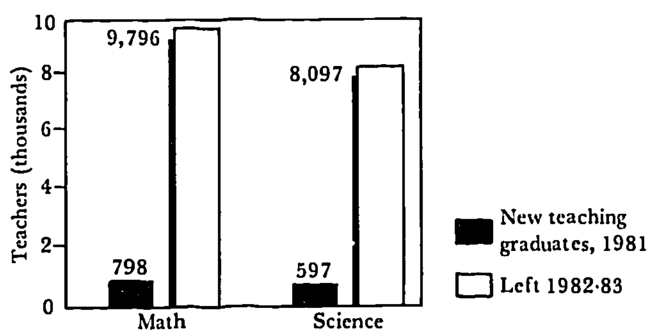
Status of the mathematics and science teaching force.



From *Beyond the Commission Reports: The Coming Crisis in Teaching* (p. 5) by L. Darling-Hammond, 1984, Santa Monica, CA: The Rand Corp. Reprinted by permission.

Figure A–13

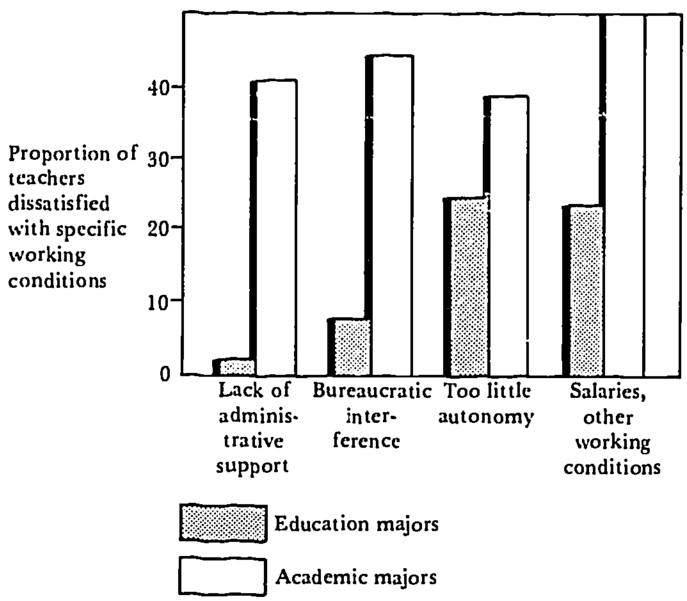
Math and science teachers: entrants and attrition.



From *Beyond the Commission Reports: The Coming Crisis in Teaching* (p. 6) by L. Darling-Hammond, 1984, Santa Monica, CA: The Rand Corp. Reprinted by permission.

Figure A–14

The best qualified teachers are the most dissatisfied.



From *Beyond the Commission Reports: The Coming Crisis in Teaching* (p. 14) by L. Darling-Hammond, 1984, Santa Monica, CA: The Rand Corp. Reprinted by permission.

Figure A–15

Opinions of public school teachers toward their profession: 1961, 1966, 1971, 1976, and 1981.

	Percent distribution of responses				
Responses	*1961*	*1966*	*1971*	*1976*	*1981*
Total	100.0	100.0	100.0	100.0	100.0
Certainly would	49.9	52.6	44.9	37.5	21.8
Male	35.2	38.0	33.0	27.3	16.0
Female	56.6	59.2	51.1	42.5	24.8
Elementary	57.3	59.6	50.1	43.5	26.4
Secondary	40.0	44.9	39.1	31.7	18.1
Under age 30	–	49.2	41.4	35.6	28.5
Age 30 to 39	–	50.9	40.1	34.5	16.2
Age 40 to 49	–	48.9	47.1	41.6	21.3
Age 50 and over	–	60.2	53.0	41.3	27.3
Probably would	26.9	25.4	29.5	26.1	24.6
Chances are about even	12.5	12.9	13.0	17.5	17.6
Probably would not	7.9	7.1	8.9	13.4	24.0
Certainly would not	2.8	2.0	3.7	5.6	12.0

– Not available.

Source: National Education Association, *Status of the American Public School Teacher*, various years.

From *Science and Engineering Education: Data and Information* (p. 92) by the National Science Foundation Office of Scientific & Engineering Personnel & Education, 1982, Washington, DC: National Science Foundation.