Chapter 3

Teachers and Teaching

Photo credit: William Mills, Montgomery County Public Schools

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Chapter 3

Teachers and Teaching

*I'll **make a deal** with you. I'll teach you math, and that's your language. With that you're going to make it. You're going to go to college and sit in the first row, not in the back, because you're going to know more than anybody.*

Jaime** Escalante, **1988

America's schools will shoulder important new responsibilities in the years to come, Well-educated workers of all kinds are looked on increasingly as economic resources.[1] Schools, parents, communities, and government at all levels are expected to educate a population that will grow more ethnically diverse in an economy that is increasingly reliant on science and technology. International competition will be invoked as a spur to excellence. The need for full participation by minorities and females will become a chronic national concern. Nowhere will these pressures be felt more strongly than in the education of scientists and engineers. The pressures, in short, will fall squarely on mathematics and science teachers.

It is a burden the teaching profession, together with school districts and teacher education institutions, is ill-equipped to meet. Fears of shortages of mathematics and science teachers now and in the future abound, and there is great concern about the poor quality of teacher training and in-service programs. The quality of teaching, in the long run, depends on the effectiveness of teachers, the adequacy of their numbers, and the extent to which they are supported by principals, curriculum specialists, technology and materials, and the wider community. Teachers of mathematics and science need to be educated to high professional standards and, like members of other professions, they need to update their skills periodically.

At the same time, research on the teaching of mathematics and science suggests that some techniques not widely used in American schools can improve achievement, transmit a more realistic picture of the enterprise of science and mathematics, and broaden participation in science and engineering by females and minorities. These techniques have been adopted slowly. Practical experiments and class discussion, for example, are slighted by many teachers in favor of lectures, book work, and "teaching to the test. " Small group learning, in which students cooperate to accomplish tasks, is also rare, although a few States are making room for it in their educational prescriptions. Teachers themselves seldom have opportunities to exchange information with their colleagues in other schools. Increasing such opportunities—for teachers and students alike—could have significant effects on, among other things, the size and quality of the national science and engineering talent pool.

[1] See, for example, National Commission on Excellence in Education, *A Nation at Risk* (Washington, DC: U.S. Government Printing Office, April 1983).

THE TEACHER WORK FORCE

Without a teacher to explain, respond, and excite students' interest, formal education is dull and limited. Scientists and engineers tell many stories about their inspiring teachers.[2] Yet the effect

[2] A decade-old series of autobiographies sponsored by the Alfred P. Sloan Foundation, including books by Freeman Dyson, Peter Medawar, Lewis Thomas, S.E. Luria, and Luis W. Alvarez, have been resoundingly successful at capturing the ". . perceptions of the individual who did the science—of how it was done, " and are designed to be ". . . important for the next generation of scientists in high school and college. " See John Walsh, "Giving the Muse a Helping Hand," Science, vol. 240, May 20, 1988, pp. ***978-979.*** The latest in the Sloan series is by 1986 Nobel laureate Rita Levi-Montalcini, *In Praise of Imperfection; My Life and Work* (New York,

(continued on next page)

that a good mathematics and science teacher has on a student's propensity to major in science and engineering cannot easily be evaluated quantitatively.

There are two major, and related, challenges that affect mathematics and science education: the first is the potential for a shortage of mathematics and science teachers, and the second is the need to improve the quality of teaching. Some fear that States and school districts will simply lower certification and hiring criteria standards in the face of possible shortages. Shortages are likely to cause problems in certain States and school districts, especially in the supply of minority mathematics and science teachers. But improving the quality of mathematics and science teaching is as important as addressing shortages.

Science and mathematics teachers are part of the entire teaching work force. In many ways, there are few differences between mathematics and science teachers and teachers of other subjects. Each are covered by the same labor contracts, belong to the same teacher unions, share the same working conditions, and are normally paid the same salaries.[3] Similarly, mathematics and science teachers share in the low esteem with which many Americans hold teaching and public education in general.[4]

In mathematics and science teaching, there are important differences between teacher preparation and assignments in elementary schools and secondary schools. Elementary teachers teach many unrelated subjects, while secondary teachers concentrate on particular subjects, such as mathematics or science (although many do both, or teach several different science fields). Accordingly, most elementary teachers are not specialists in any subject. They normally hold baccalaureate degrees in education and have had relatively little science and mathematics coursework (if any) at college. Most secondary teachers, however, have taken many mathematics and science courses in college; some have an undergraduate degree in these disciplines.[5]

The Possibility of Mathematics and Science Teacher Shortages

Many observers are worried about possible future shortages of teachers, and, reportedly, in some geographic areas it is already difficult to hire adequate numbers of mathematics and science teachers.[6] It is widely believed that shortages of

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NY: Basic Books, 1988). Also see Daryl E. Chubin et al., "Science and Society," ***Issues in*** Science& ***Technology,*** vol. 4, summer 1988, pp. 104-105.

[3]An ongoing controversy related to the entire teacher work force is the role of unions. Some people think that teacher unions, through their sometimes stubborn resistance to change, ***are*** the cause of many problems in education. These problems include the difficulty in firing poor teachers and in staffing "difficult" schools, the devotion to the "seniority" principle (rather than teacher's merits) shown in allocating salary increases, and the potential barrier to meaningful reforms erected by the granting of "tenure" to teachers. Others think that teacher unions can be of great help in providing a single point of negotiation for many aspects of teachers' working lives and conditions, forging teachers into a profession based on common, self-specified norms and goals of conduct, and encouraging teachers to become *more* reflective of their tasks. There are two main teacher unions, the American Federation of Teachers and the National Education Association. Their leaders are visible in the national debate on reforming American education, often calling for greater public spending on education, and their positions have frequently been at odds with those of the U.S. Secretary of Education. There is no indication that the form and extent of union activity in mathematics and science teaching is any different from that for teaching as a whole (although there are special professional associations of such teachers, such as the National Science Teachers Association and National Council of Teachers of Mathematics). The positive and negative impacts of teacher unions are not considered further in this report.

[4]For example, surveys show that the percentage of Americans that would like their children to become public school teachers has fallen from 75 percent in 1969 to 45 percent in 1983. In a similar survey in 1981, Americans ranked clergymen, medical doctors, judges, bankers, lawyers, and business executives as being in professions with higher prestige and status than public school teaching. Only local political officeholders, realtors, funeral directors, and advertising practitioners were ranked lower. Stanley M. Elam (cd.), ***The Phi Delta Kappa Gallup Polls of Attitudes Toward Education*** *1969-1984: A Topical Summary* (Bloomington, IN: Phi Delta Kappa, 1984).

[5]Most new teachers were education majors in college. Many, however, were single subject (such as physics) majors directly inducted into the teaching force or are taking supplementary education courses. The utility of the education major is under serious reconsideration at the moment and several groups have proposed a wide-ranging overhaul of teacher education. This is discussed later under "Preservice Education. "

[6]See National Science Board, ***Science and Engineering Indicators –1987*** (Washington, DC: U.S. Government Printing Office, ***1987),*** pp. ***27-32;*** and Linda Darling-Hammond, ***Beyond the Commission Reports: The Coming Crisis*** in Teaching, RAND/4-3177-RC (Washington, DC: Rand Corp., July 1984). Henry M. Levin, Institute for Research on Educational Finance and Governance, School of Education, Stanford University, "Solving the Shortage of Mathematics and Science Teachers, " January 1985, finds that shortages, in some form, have existed for ***40*** years, primarily because of the low salaries offered to mathematics and science teachers.

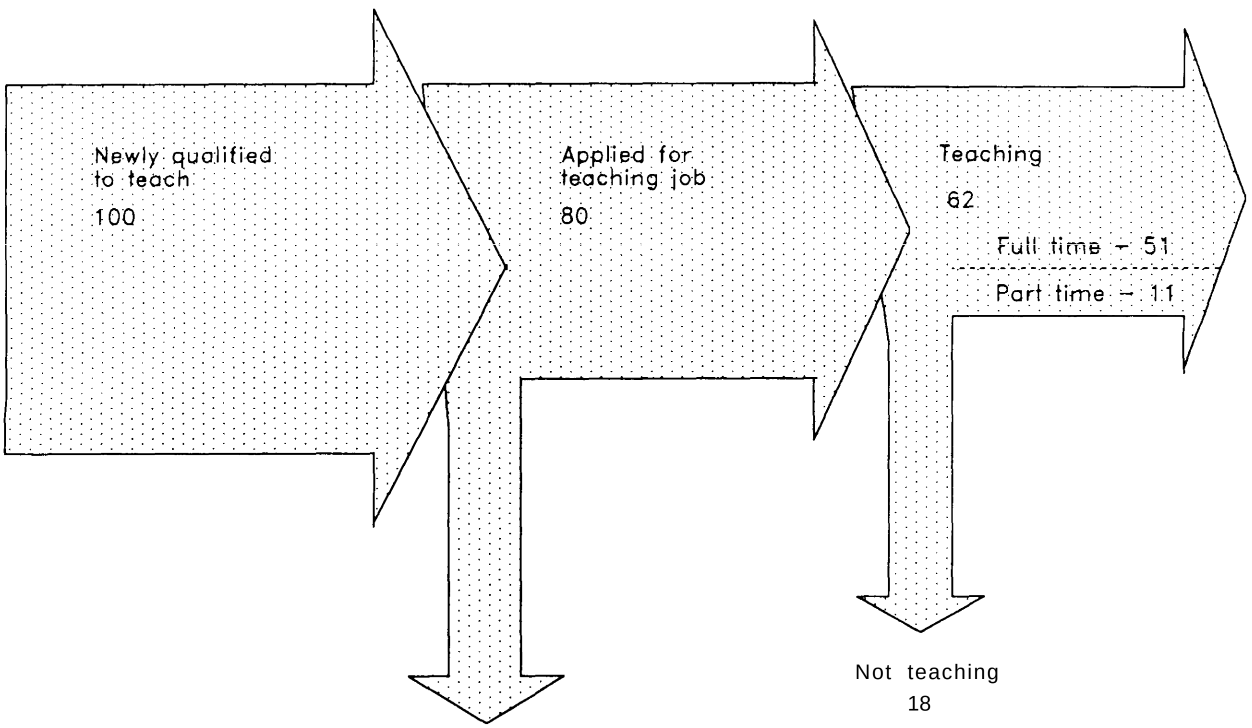
teachers of all kinds are imminent due to an increase in the number of teachers approaching retirement and a decrease in the number of college freshmen planning to become teachers during the last decade. In the aggregate, these trends affect the size of the teacher work force. But it is events in the middle stages of teachers' careers as well that predict future supply and demand. For example, many fully qualified teachers leave the profession (perhaps to start families), and may be lured to return to schools in due course.

To estimate whether there will be a shortage, and what its effects might be, it is necessary to have data on the future work plans of the existing teaching work force, the rates of entry to and exit from it, the extent to which these rates change in response to market signals, and what measures might reduce the effect of any shortage. A conceptual model of entry to and exit from the teacher work force is depicted in figure 3-1.

Current estimates of the rates of entry to and exit from the teaching work force are very poor and often inconsistent.[7] It is not possible, therefore, to determine with any certainty whether

[7] Lynn Olson and Blake Rodman, "Is There a Teacher Shortage? It's Anyone's Guess, " *Education Week,* June 24, 1987, pp. 1, 14-16; and Blake Rodman, "Teacher Shortage Is Unlikely, Labor Bureau Report Claims," *Education Week,* Jan. 14, 1987, p. 7. Data, much of it conflicting, is collected and reported by the National Education Association, the U.S. Bureau of Labor Statistics, and the Department of Education, The inadequacy of databases on teachers is also revealed through the absence of reliable estimates of the number of uncertified teachers teaching or the number teaching outside their field of certification. The Center for Education Statistics is conducting a new survey, the results of which should be available in early 1989. Simultaneously, the National Academy of Sciences is examining future research needs on this issue, while the Council of Chief State School Officers is also trying to assemble disparate State data.

Figure 3-l.—Career Paths of 100 Newly Qualified Teachers, About 1 Year After Graduation, 1976.84



NOTE: "Newly qualified teachers" are defined as those graduates who were eligible for a teaching certificate or who were teaching at the time of the survey (and who had never taught full time before receiving this bachelor's degree). Bachelor's graduates are surveyed about 1 year after graduation.

SOURCE: Office of Technology Assessment, 1988; based on combined data from U.S. Department of Education, '(Recent College Graduate Surveys of 1976-77, 1979-80, and 1983 -84," unpublished data. Career pattern is similar in all years, there will be a shortage, what its effects might be, or what the special aspects of the problem will be for mathematics and science teaching. Some aspects include:

- How intensified competition for new science and engineering baccalaureates will reduce the already small incentives for new graduates to consider mathematics and science teaching careers.
- The extent to which mathematics and science teachers who are already qualified but working in other occupations could be lured back to classroom teaching in response to higher salaries or changes in working conditions.
- The extent to which working and retired scientists and engineers could be retrained to enter the teaching work force. Several programs are attempting to retrain such people.
- How attrition of existing teachers (currently between 5 and 10 percent annually) can be reduced.[8] (See box 3-A.)
- The extent to which changes, such as the introduction of less restrictive certification requirements, the use of uncertified teachers, and the assignment of existing teachers out of their main teaching fields to teach mathematics and science classes, could cover shortages.
- How the use of part-time teachers, master teachers, or teaching assistantships could compensate for any shortages.
- The extent to which greater use of technologies, including computers, video recorders, and distance learning techniques, could reduce the need for mathematics and science teachers.[9]

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8 A survey of teacher attrition, based on followups of the National Longitudinal Survey of 1972, is in Barbara Heyns, "Educational Defectors: A First Look at Teacher Attrition in the NLS-72," ***Educational Researcher,*** April 1988, pp. 24-32. One surprising finding of this and other studies (such as the U.S. Department of Education's Survey of Recent College Graduates) is that a large number of those who complete teacher training programs never, in fact, teach. In the 9 years between 1977 and 1986, one-quarter of those qualified never taught, and 40 percent of those who became newly qualified teachers in 1983-84 had not become teachers by 1985. See also Richard J. Murnane, "Understanding Teacher Attrition," ***Harvard Educational Review, vol. 57, No. 2,*** May 1987, pp. 177-182, which finds that chemistry and physics teachers in Michigan in the 1970s were likely to leave teaching faster than were biology and history teachers.

9 There is no evidence that technology replaces teachers. The use of satellite, cable, and other telecommunications technologies en-

Box 3-A.—Reasons Why Physics Teachers Leave High School Teaching

A 1983 survey reported some of the reasons why physics teachers leave teaching.[1] Those with a graduate degree in physics can readily find well-paying jobs in industry; either they never enter the teaching profession or they hastily depart. In general, the survey found, physics teachers leave for the following reasons:

- Instructional laboratories are poorly equipped and budgets are inadequate for making improvements.
- It is difficult to remain professionally active. There are seldom funds for teachers to attend professional meetings, to keep up-to-date with scientific literature and advances, or to meet and share experiences with teachers in other schools. This feeds a sense of isolation.
- Accountability to local, State, and Federal bodies has multiplied both teacher paperwork and administrative duties.
- There is a lack of identification by most school administrators with the problems that interfere with quality science teaching. School administrators, the survey reports, are often not interested in improving teaching.
- There is a lack of respect within the local community. Like teachers of all subjects, physics teachers are often criticized in school board meetings as being greedy and inefficient, particularly when funding decisions are made.
- Voters do not support the schools, as evidenced by the willingness to vote down school bond issues in the early-1980s, even at the expense of reductions in the size and quality of the teaching work force. This strong pressure to cut taxes is especially evident in smaller communities whose demographics favor needs other than those of the student population.

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[1] For reasons Wily physics teachers leave teaching, see Beverly Fearn Porter and William H. K&Y. "Why Physicists Leave Teaching," *Physics Today*, September 1983, pp. 32-37. Also see American Association of Physics Teachers, *The Role, Education, and* - *cations of the High School Physics Teacher* (College Park, MD: AAPT Committee on Special Projects for High School Physics, 1988). As this technical memorandum went to press, the American Institute of Physics released a new report, Michael Neuschatz and Maude Covalt, *Physics in the High Schools: Findings From the 1986-87 Nationwide Survey of Secondary School Teachers of Physics* (New York, NY: American Institute of Physics, 19ss).

Some secondary school principals are having difficulty hiring science teachers and (to a lesser extent) mathematics teachers. The 1985-86 National Survey of Science and Mathematics Education found that 70 percent of secondary school principals said that they were having difficulty hiring physics teachers, **60** percent were having difficulty with chemistry and computer science teachers, and over **30** percent were having difficulty locating biology and life sciences teachers. The survey found that few schools had incentive programs to attract teachers to shortage fields; retraining programs are the more common method of supplying shortage fields.[10]

After years of declining interest among college freshmen in becoming teachers, there has been an upturn since 1986.[11] A 1985-86 survey estimated that about 20 percent of science and mathematics teachers are expected to retire in the next decade.[12] The result of these opposite trends is anybody's guess, so speculations abound.

Salaries

Many policy makers and educators point to the generally low level of teachers' salaries and claim that neither the number nor the quality of mathematics and science teachers can be improved until these salaries are increased substantially.[13] In fact, teachers' salaries are rising. In real terms, average annual public school teacher salaries fell during the 1970s by about 10 percent from their all-time high in the early 1970s. By 1984-85, they had risen to just under what they were in 1969-70. The mean teacher salary in 1986 was about $25,000, but with large variations among the States.[14] The effects of these increases on teacher supply and quality, which take time to show up, may yet be very positive. Already, there is some increased interest among college freshmen in teaching careers.

The attractiveness of different occupations to new college graduates is shaped by the immediate starting salaries as well as prospective long-term earnings. Students with considerable debts from their baccalaureate education, it is argued, need a substantial source of income to start paying off these debts. Starting teaching salaries have consistently been lower than those in other professions, and have not increased as rapidly during the last decade. (See figure **3-2.**)

A particular controversy for mathematics and science teachers is whether they should be paid more than other teachers in order to attract people to fill shortages. A recent survey indicated that a majority of secondary mathematics and science teachers would support differential pay of this kind, and many principals are also in favor of this. Support among those who teach mathematics and science at the elementary level is weaker. Traditionally, teacher unions have argued that teachers should be paid the same, regardless of their subject specialization.[15]

Minority Teachers

Because of the declining proportion of Blacks and Hispanics entering college and because of the expanded career options now open to them, the

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ables school districts to provide instruction from one site to many sites—but teachers are not replaced. Instead, these distance learning projects aggregate sparsely populated classrooms of two or three students to more "regular" sized classrooms (Linda Roberts, Office of Technology Assessment, personal communication, September 1988)

[10]Iris R. Weiss, ***Report of the 1985-86 National Survey of Science and Mathematics Education*** (Research Triangle Park, NC: Research Triangle Institute, November 1987), tables 72, 73.

[11]For the recent upturn in college freshmen interest in education majors, see Robert Rothman, "Proportion of College Freshmen Interested in a Career in Teaching Up, Survey Finds," *Education Week*, *vol. 7,* Jan. 20, 1988, pp. 1, 5. Eight percent of 1987 college freshmen planned teaching careers, up from *4.7* percent in 1982, but well below the 20 percent level in the early 1970s. The number of physics baccalaureates entering teaching also increased from only ***23*** in 1981 to about 100 in ***1986*** (of a total of 5,214 physics degree recipients in 1986). ***Physics Today,*** "Survey of Physics Bachelors Finds That More Plan to Teach,'r September 1987, p. 76.

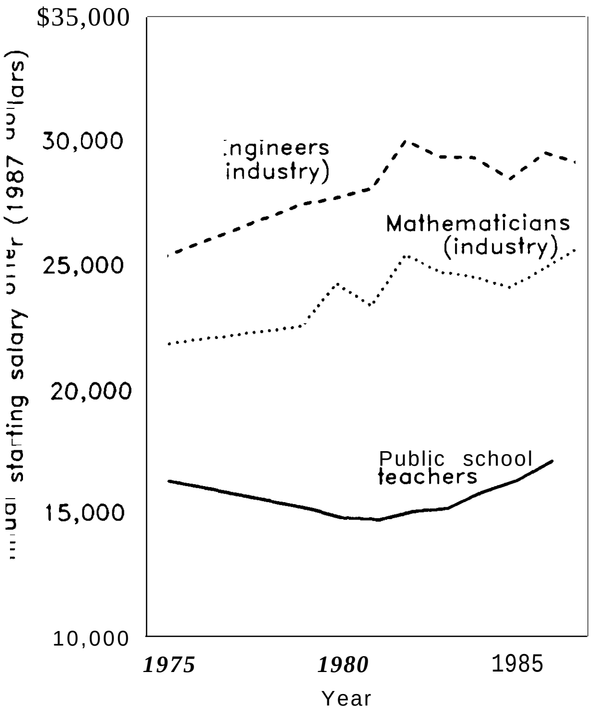
[12]Weiss, op. cit., footnote 10, p. 64, table 36.

[13]Salaries are important, but are not the only factor that affects whether ***teachers enter or remain*** in teaching. Working conditions and the wider societal perception of the value of school teaching are also important influences. See, for example, Russell W. Rumberger, "The Impact of Salary Differentials on Teacher Shortages and Turnover: The Case of Mathematics and Science Teachers," *Economics of Education Review, vol. 6, No. 4, 1987,* pp. 389-399. Rumberger finds that the disparity between engineering and mathematics 'science teaching salaries has some effect on teacher shortages and turnover; the disparity, however, offers far less than a complete explanation.

[14]For example, between *1969-70* and 1984-85, Alaska teacher salaries dropped by 34 percent in real terms, whereas those in Wyoming and Texas rose by 14 percent. U.S. Department of Education, Office of Educational Research and Improvement, Center for Education Statistics, *Digest of* ***Education Statistics 1987*** (Washington, DC: U.S. Government Printing Office, May 1987), tables 51-53.

[15]Weiss, op. cit., footnote 10, table 74.

Figure 3-2.-Starting Salaries for Teachers, Compared to Other Baccalaureates in Industry, 1975.87 (constant 1987 dollars)



NOTE: Uses gross national product deflator. Industry estimates of salary offers are baaed on a survey of selected companies; this may tend to inflate salaries slightly. The teacher data are "minimum mean" salary, from the National Education Association, and probably are underestimates. Various other salary surveys report slightly different data. However, the basic message remains the same: teachers are paid much less than most other baccalaureates.

SOURCE: U.S. Department of Commerce, Statistical *Abstract of the United States* (Washington, DC: U.S. Government Printing Office, 1888), p. 130; based on data from The Northwestern Endicott-Lindquist Report, Northwestern University.

number of minorities electing teaching careers is declining. There are, in the first instance, comparatively few Black or Hispanic mathematics and science teachers. Data from a recent survey (see table 3-1) indicate that the majority of Black teachers are in the elementary grades; only 3 percent and 5 percent, respectively, of mathematics and science teachers in grades 10 to 12 are Black. Only 1 percent of teachers of both these subjects are Hispanic. For now, the proportion of minorities in the teaching force is increasing slightly, but several commentators warn of future shortages of minority teachers, particularly in mathematics and science. Such a shortage poses particular problems to schools with high minority enrollments, denying minority children role

Table 3-1 .- Mathematics and Science Teachers, by Race and Ethnicity, 1985.86 (in percent)

Subject and grade	Black	Hispanic	White	other[a]	Unknown
Mathmatics					
K-3	10	1	84	0	4
4-6.	12	2	84	0	2
7-9. ., ...	6	1	90	1	3
10-12	3	1	94	1	1
Science					
K-3	**9**	**4**	**82**	1	**4**
4-6.	**8**	**4**	**86**	1	1
7-9.	**5**	1	**88**	1	**4**
10-12	**5**	1	**92**	**2**	1

[a]Includes Native American, Alaskan Native, Asian, and Pacific Islander.

NOTE: Some rows do not sum to 100 percent due to rounding.

SOURCE: Iris R. Weiss, Report *of the 1985-86 National* Survey *of Science arrd* Mathematics *Education* (Research Triangle Park, NC: Research Triangle Institute, November 1987), table 35

models (among other things that minority teachers provide). Making higher education more attractive and attainable for future Black and Hispanic teachers will help increase the supply of the minority teaching force.[16]

Certification and Misassignment of Mathematics and Science Teachers

Each State sets specifications, designed to ensure a minimum level of professional competence, for the academic preparation of teachers. These specifications, which take the form of requirements for a minimum number and combination of college-level courses in mathematics, science, and education, are enforced through certification and periodic recertification of teachers. Certification requirements vary considerably from State to State (see table 3-2), and there are differences in the extent to which they are enforced. The States may also require examinations, such as the National Teachers' Examination, for either initial certification or later recertification .17

[16]Shirley M. McBay, ***Increasing the Number and Quality of Minority Science and Mathematics Teachers (New*** York, NY: Carnegie Forum on Education and the Economy, Task Force on Teaching as a Profession, January 1986); Patricia Albjerg Graham, "Black Teachers: A Drastically Scarce Resource, " *Phi Delta Kappan*, April 1987, pp. 598-605; and Blake Rodman, "AACTE Outlines Plan to Recruit Minorities Into Teaching, " *Education Week*, Jan. 13, 1988, p. 6.

[17]At the elementary level, most teachers are certified as elementary teachers without particular specialization, but, at the secondary level, some specialization in certification is the norm. About one-half of the States license secondary teachers to teach in any science subject, while others restrict certification to a particular field,

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Table 3-2.—Mathematics and Science Teacher Certification Requirements by State, June 1987

	Course credits by certification field						
	Math	Science, Broad-field	Biology, Chemistry, Physics	Earth Science	General science	Teaching methods: science/math	Supervise teaching experience
Alabama	27	52	27	27	27	Yes	9
Alaska	None	None	None	None	None	No	None
Arizona	30	30	30	30	30	Yes	8
Arkansas	21		24	24	24	No	12wks
California	45		45			No	a
Colorado	b	b	b	b	b	Yes	400hrs
Connecticut	18		18	18	21	No	6
Delaware	30		39-45	39	36	Yes	6
District of Columbia	27	30	30	30	30	Yes	1 sem
Florida	21		20	20	20	Yes(S)	6
Georgia (effective 9/88)	60qtr	45qtr	40qtr	40qtr		Yes(M)	15qtr
Guam	18	18				NO	None
Hawaii			b	b	b		
Idaho	20	45	20	20		No	6
Illinois	24	32	24	24		Yes	5
Indiana	36		36	36	36	Yes	9wks
Iowa	24	24	24	24	24	Yes	Yes
Kansas							
Kentucky	30	48	30	30		No	9-12
Louisiana	20		20	20	32	No	9
Maine	18	18				Yes	6
Maryland	24	36	24	24	36	Yes	6
Massachusetts	36	36	36	36	36	Yes	300 hrs
Michigan	30	36	30	30		No	6
Minnesota	c	c	c	c	c	c	1 qtr
Mississippi	24		32	32	32	Yes(S)	6
Missouri	30	30	20	20	20	Yes	8
Montana	30qtr	60qtr	30qtr	30qtr	30qtr	Yes	10wks
Nebraska	30	45	24	24		Yes	320hrs
Nevada	16	36	16	16	16	No	8
New Hampsshire	b	b	b	b	b	b	b
New Jersey	30	30	30	30	30	No	c
New Mexico	24	24	24	24	24	Yes	6
New York	24		36	36	36	No	Yes
North Carolina	c	c	c	c	c	Yes	6
North Dakota	c	c	c	c	c	Yes	8
Ohio	30	60	30	30	30	Yes	a
Oklahoma	40	40	40	40	40	No	12wks
Oregon	21	45	45	45	45	Yes(M)	15qtr
Pennsylvania	b						b
Puerto Rico	30	30	30		30	Yes	3(S)5(M)
Rhode Island	30	30	30		30	Yes	6
South Carolina	24	30	12		18	Yes(M)	6
South Dakota	18	21	12	12	18	No	6
Tennessee	36qtr	48qtr	24 qtr	24qtr	24qtr	Yes	4
Texas	24	48	24	24		No	6
Utah	c	c	c	c	c	Yes	12
Vermont	18	18	18	18	18	Yes	None
Virginia	27		24	24	30	No	6
Virgin Islands	24	NA	NA	NA	NA	No	Yes
Washington	24	51	24	24		No	15
West Virginia	c	c	c	c	c	c	c
Wisconsin	34	54	34	34	34	Yes	5
Wyoming	24	30	12	12	12	No	1 course

KEY: Course credits = semester credit hours, unless otherwise specified; qtr = quarter credit hours, M = mathematics only, S = science only; NA = not available, blank space = no certification offered.

[a] 1 semester full time or 2 semesters half time—California; supervised teaching experience and 300 hours clinical/field-based experience—Ohio.

[b] Certification requirements determined by degree-granting institution or approved competency-based program.

[c] Major or minor—North Dakota, Utah; 2/3 to 40 percent of program—Minnesota and North Carolina; courses matched with job requirements—West Virginia

SOURCE: Rolf Blank and Pamela Espenshade, *State Education Policies Related to Science and Mathematics* (Washington, DC: Council of Chief State School Officers, State Education Assessment Center Science and Mathematics Indicators Project, November 1987), table 4

Photo credit: William Mills, Montgomery County Public Schools

There are few minority teachers in mathematics and science to serve as role models for Black, Hispanic, and Native American children.

As part of the education reform movement, policy makers have tightened certification standards in the hope of raising the quality of teaching. Altering certification requirements may be an easy control on the system for policy makers to enact, but have little effect on actual classroom practices and teaching quality. However, some teachers teach without certification, either because they are new to the State and are working to achieve accreditation (and are teaching on an "emergency" basis) or because they are teaching subjects other than those which they are certified to teach.[18] An increasing number of science

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such as physics. In each case, typical requirements are *24* to *36* sernester-hours of college-level science courses. Ken Mechling, "Science Teacher Certification Standards: An Agenda for Improvement, " ***Redesigning Science and Technology Education: 1984 Yearbook of*** *the National* ***Science Teachers Association,*** Rodger W. By bee et al. (eds.) (Washington, DC: National Science Teachers Association, 1984), pp. 157-161.

[18]Data on the extent to which "uncertified" teachers are in charge of mathematics and science classes are fragmented and often inconsistent. Analysts differ on the interpretation of uncertified: sometimes the term is interpreted as including those without any kind of certification, sometimes it includes teachers who are certified but are teaching out of their main field of competence or certification (the two are not always the same), and other times it is used to inelude teachers who have provisional or emergency certification, but not full certification. (To the extent that there is great flexibility to

teachers, in particular, appear to be teaching subjects that they are either not licensed or not qualified to teach. A 1986 survey of 39 States (enrolling 28 percent of the student population) estimated that between 6 and 15 percent of all science teachers were uncertified in the field they were hired to teach. Biology had the lowest proportion of uncertified teachers, while earth and general science had the highest. About *8* percent of mathematics teachers were uncertified in that field.[19] The proportion of uncertified mathematics and science teachers was greatest in the Southeast region of the country. A 1985-86 survey indicates that as many as 20 percent of science teachers in grades 10 to 12 are not certified to teach the courses they are teaching: 4 percent are not certified at all, **6** percent have provisional certification, and 5 percent are certified in other fields (the remainder are presumably those certified in one science subject but teaching another). This same survey found that, of teachers of mathematics in grades **10** to 12, 4 percent were not certified at all and 4 percent had only provisional certification, while **10** percent were certified in fields other than mathematics. In total, 14 percent of these teachers were teaching courses that they were uncertified to teach .20

National data from the National Science Teachers Association (NSTA) indicate that the notion that a high school science teacher teaches only one science is increasingly a myth. And many science teachers teach mathematics or conscience subjects as well. On average, about *8* percent of the course assignment of secondary science teachers is in mathematics, and 5 percent is in conscience subjects. For example, about half of the teaching load of chemistry teachers is in chemistry, 12 percent in biology, and 15 percent in physics and general physical science.[21]

This pattern is reflected in the teaching of all subjects at the secondary level. The National Education Association estimates that ***83*** percent of all subject specialist secondary teachers devote all their teaching time to teaching the field that was their college major; 7 percent spend between **50** and 100 percent of their time in that field; and only 10 percent spend less than 50 percent of their time teaching in that field.[22]

While States condemn teaching without adequate certification, critics of the system of certification note that States tacitly condone it by permitting waivers of requirements and by failing to enforce certification requirements.[23] To the extent that shortages exist, States, school districts, or principals must choose whether it would be better to have a poorly qualified teacher teaching a science class than to have no teacher and no class at all.

A number of States have developed alternative certification routes for mature entrants to the teaching profession, particularly those who are already qualified scientists, engineers, or technicians. These programs focus particularly on recruiting mathematics and science teachers. A recent study estimates that there are **26** such programs nationally, and some have attracted Federal funding.[24]

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issue such certification, States and school districts have an easy way to rectify any concerns about the number of uncertified teachers in the classroom.) Principals reportedly prefer often to retain existing uncertified teachers in classes where they have developed rapport with the class than introduce new, inexperienced, but fully certified teachers who would have much more difficulty teaching the class.

"Joanne Capper, ***A Study of Certified Teacher Availability in the*** States (Washington, DC: Council of Chief State School Officers, February *1987).* These data are drawn from State needs assessments, mandated under Title II of the Education for Economic Security Act of 1984; the data analysis was funded by the National Science Foundation.

[20] Weiss, op. cit., footnote 10, table ***46.***

[21] Bill G. Aldridge, "What's Being Taught and Who's Teaching It, " ***The Science Curriculum: The Report of the*** *1986 National Forum* ***for School Science,*** Audrey B. Champagne and Leslie E. Hornig (eds.) (Washington, DC: American Association for the Advancement of Science, 1987), pp. 207-223.

[22] National Education Association, ***Status of the American Public School Teacher 1985/86*** (West Haven, CT: National Education Association, 1987), table 18. These data are based on a definition of misassignment as teachers assigned outside their main college preparatory field. This is an imperfect measure, because some teachers are qualified to teach in subjects that were not their college major.

[23] American Federation of Teachers / Council for Basic Education, ***Making Do in the Classroom: A Report on the Misassignment of Teachers*** (Washington, DC: ***1985);*** Aldridge, op. cit., footnote 21, 1985, p. 84.

[24] These programs enjoy some success, but data on their impact are very limited. Anecdotal evidence suggests that those who make such transitions are not likely to be the best and the brightest in their fields of origin, but there is no way (yet) of judging their quality relative to teachers in the field they have joined. See Linda Darling-Hammond and Lisa Hudson, Rand Corp., "Precollege Science and Mathematics Teachers: Supply, Demand, and Quality, "

(continued on next page)

These programs look promising, and could be expanded in the interests both of the quantity and quality of the entry-level science and mathematics work force. New York City has a program to relicense teachers of subjects other than mathematics and science in these fields. (See box 3-B.)

In an interesting initiative in Hammond, Indiana, a chemistry teacher works part time in a local steel company and part time in the local high school. His salary is shared by the school district and the company, and some of his classes are taught in the industrial research laboratory. This arrangement originated in the enthusiasm of the teacher and the local community, and could be replicated elsewhere.[25]

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mimeo, 1987, p. 51; Shirley R. Fox, ***Scientists in the Classroom: Two Strategies*** (Washington, DC: National Institute for Work and Learning, 1986); and Nancy E. Adelman et al., An ***Exploratory Study of Teacher Alternative Certification and Retraining Programs*** (Washington, DC: Policy Studies Associates, Inc., October 1986).

[25] Brent Williamson, high school teacher, personal communication, February 1988.

Box 3-B.—Mathematics and Science Relicensing Board

During the summer of 1984, the New York City Board of Education decided to retrain teachers of other subjects to teach mathematics and science.[1] The board realized that urban schools were most vulnerable to any future teacher shortage, because the staffs of such schools are typically older than their suburban counterparts and because teachers prefer to work in suburban school systems. On average, the proportion of New York's teaching force that will retire soon is about twice that of the national teacher work force. The Mathematics and Science Relicensing Board's task is to "re-tool" teachers of subjects such as English and history in which there is a teacher surplus, and, by April 1987, had succeeded in awarding 400 licenses in mathematics and science. These recertified teachers are primarily female and minority; data from 1985 indicate that 61 percent of program participants were women and 45 percent were Black or Hispanic, percentages that were considerably higher than those of the teaching force of New York City as a whole (approximately 22 percent of secondary school teachers of all subjects are members of minority groups and 50 percent are female). The participants think that their new licenses will make them more mobile and give them the challenge of working in a new field.

The recertification program was free to the teachers, and took place after hours and in the summer at nearby universities and colleges. These classes were arranged especially for the Relicensing Board, and cost between $45 to $70 per credit, depending on the class and university. The academic program is similar to an undergraduate major, and teachers can be simultaneously certified in different subjects, as well as at different levels. After coursework is completed, candidates must pass a city-wide examination, and, after passing, take a probationary position as a teacher in the new field. After 2 years, tenure is reviewed. If granted, the licensees are certified both for course and probationary period completion. Seminars and tutorials are also offered to assist in preparation.

The program benefits from its cooperative model; it is the only one in the United States that brings together so many different institutions and groups with an interest in staffing city classrooms. Funds come from the city, advertising is by courtesy of the United Federation of Teachers, the Board of Education approves the program, the Division of Curriculum and Instruction establishes and manages the program, and 11 universities and colleges take part. Everyone benefits, particularly the academic institutions that have a strong interest in improving the level of preparation of their future students.

An important benefit of the board has been that the large number of Black, Hispanic, and female teachers trained through the program has increased the interest of their minority and female students in mathematics and science. An evaluation of the program is in progress.

[1] Bruce S. Cooper, "Retooling Teachers: The New York Experience, *Phi Delta Kappan*, vol. 68, No. 8, April 1987, pp. 606-609.

THE PROFESSIONAL STATUS OF THE TEACHING WORK FORCE

Concern about teacher shortages and quality comes at a time when the teaching profession as a whole feels embattled and undervalued, but also recognizes its key role in education and in education reform. Seemingly endless commission reports have cited the need to give greater status, more recognition, and higher salaries to teachers.[26] Although teachers aspire to belong to a profession, few feel that they truly do. Many argue that administrators and school boards, not teachers, define standards of conduct in schools, teaching methods, and curricula. Teachers are constrained by many rules and regulations, many of which conflict with each other and which, taken together, sap the enthusiasm of many teachers. In some ways, the process of increasing requirements and paperwork is a kind of "de-skilling" of the teaching work force: the skill of teaching is removed from teachers and given to those who make and enforce the "rules."[27]

One way of redressing the balance is to give teachers more say in setting the professional qualifications and standards for membership in the teaching force. The recommendation of the Carnegie Task Force on Teaching as a Profession for a national certification board is being implemented; its first members were nominated in May 1987. Eventually, such certification might replace State certification. Parallel moves are afoot in the mathematics and science teaching profession. In 1984, NSTA estimated that about 30 percent of all secondary mathematics and science teachers were either "completely unqualified or severely underqualified" to teach these subjects.[28] NSTA launched its own certification program for science teachers in October 1986. The fact that many "single-subject" teachers teach a good deal of other sciences and mathematics has led NSTA to devise a two-track secondary certification program: one for general science teaching, the other for single-subject science teaching. Currently, fewer than one-third of the science teaching force would meet NSTA'S standards.[29] The guidelines of both NSTA and the National Council of Teachers of Mathematics (NCTM, set in **1981)** are listed in table 3-3.

The Quality of Mathematics and Science Teachers

Mathematics and science teacher quality is not easily measured.[30] There are three related and commonly used indicators of teacher quality: possession of State certification, conformity to guidelines established by such bodies as NSTA and NCTM, and the amount of college-level coursework that teachers have had (on which the other two indicators are based). Many commentators caution against equating course preparation with teacher quality. Nevertheless, reliable data exist only for this measure and it is the one used here, along with teachers' own perceptions of their confidence and abilities.[31]

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[26] See, for example, Task Force on Teaching as a Profession, ***A Nation Prepared: Teachers for the 21st Century*** (New York, NY: Carnegie Forum on Education and the Economy, 1986); National Commission for Excellence in Teacher Education, ***Call for Change in Teacher Education*** (Washington, DC: American Association of Colleges for Teacher Education, 1985); National Science Board, Commission on Precollege Education in Mathematics, Science, and Technology, ***Educating Americans for the 21st Century*** (Washington, DC: 1983); and Paul E. Peterson, "Did the Education Commissions Say Anything?" ***The Brookings Review,*** winter 1983, pp. 3-11. See also The Carnegie Foundation for the Advancement of Teaching, ***Report Card on School Reform: The Teachers Speak*** (Washington, DC: 1988), which characterizes recent reforms as involving greater regulation of easily manipulated elements of education (such as graduation requirements, testing for minimum competency, requirements on teacher preparation, and tester testing) rather than renewal. Teachers have largely not been involved in these reforms, only ordered to undertake them. Nearly one-half of teachers report that morale in teaching has actually fallen since 1983, when the current wave of reforms began.

[27] Martin Carnoy and Henry M. Levin, ***Schooling and Work in the Democratic State*** (Stanford, CA: Stanford University Press, 1985), pp. 157-158.

[28] K.L. Johnston and B.G. Aldridge, "The Crisis in Science Education: What Is It? How Can We Respond?" ***Journal of College Science Teaching*** (September/October 1984), quoted in National Science Board, op. cit., footnote 6, p. 37.

[29] John Walsh, "Teacher Certification program Under Way," ***Science,*** vol. 235, Feb. 20, 1987, pp. 838-839; and Robert Rothman, "Science Teachers Laud Certification Program, But Few Seen Qualified," ***Education Week,*** Apr. 8, 1987, pp. 6, 10.

[30] See, generally, Darling-Hammond and Hudson, op. cit., footnote 24.

[31] Rolf K. Blank and Senta A. Raizen, National Research Council, "Background Paper for a Planning Conference on a Study of Teacher Quality in Science and Mathematics Education," unpublished working paper, April 1985. Unfortunately, few people seem to have asked the consumers of this teaching, the students, what they think of their teachers' abilities. Better ways of measuring quality might be either to observe teachers' performance in the class-

(continued on next page)

Table 3=3.—Guidelines for Mathematics and Science Teacher Qualifications Specified by the National Council of Teachers of Mathematics (NCTM) and the National Science Teachers Association (NSTA)

NCTM guidelines	NSTA standards
Early elementary **school** The following three courses, each of which presumes a prerequisite of 2 years of high school algebra and 1 year of geometry: 1. number systems 2. informal geometry 3. mathematics teaching methods ***Upper elementary and middle school*** The following four courses, each of which presumes a prerequisite of 2 years of high school algebra and 1 year of geometry: 1. number systems 2. informal geometry 3. topics in mathematics (including real number systems, probability and statistics, coordinate geometry, and number theory) 4. mathematics methods ***Junior high school*** The following seven courses, each with a prerequisite of 3 to 4 years of high school mathematics, beginning with algebra and including trigonometry: 1. calculus 2. geometry 3. computer science 4. abstract algebra 5. mathematics applications 6. probability and statistics 7. mathematics methods ***Senior high school*** The following 13 courses, which constitute an undergraduate major in mathematics, and which each presume a prerequisite of 3 to 4 years of high school mathematics, beginning with algebra and including trigonometry: 1-3. three semesters of calculus 4. computer science 5-6. linear and abstract algebra 7. geometry 8. probability and statistics 9-12. one course each in: mathematics methods, mathematics applications, selected topics, and the history of mathematics 13. at least one additional mathematics elective course	***Elementary level*** 1. Minimum 12 semester-hours in laboratory- or field-oriented science including courses in biological, physical, and earth sciences. These courses should provide science content that is applicable to elementary classrooms. 2. Minimum of one course in elementary science methods (approximately 3 semester-hours) to be taken after completion of content courses. 3. Field experience in teaching science to elementary students. ***Middle/junior high school level*** 1. Minimum 36 semester-hours of science instruction with at least 9 hours in each of biological or earth science, physical science, and earth/space science. Remaining 9 hours should be science electives. 2. Minimum of 9 semester-hours in support areas of mathematics and computer science. 3. A science methods course designed for the middle school level. 4. Observation and field experience with early adolescent science classes. ***Secondary level*** General standards for all science specialization areas: 1. Minimum 50 semester-hours of coursework in one or more sciences, plus study in related fields of mathematics, statistics, and computer applications. 2. Three to five semester-hour course in science methods and curriculum. 3. Field experiences in secondary science classrooms at more than one grade level or more than one science area. ***Specialized standards*** 1. Biology: minimum 32 semester-hours of biology plus 16 semester-hours in other sciences. 2. Chemistry: minimum 32 semester-hours of chemistry plus 16 semester-hours in other sciences. 3. Earth/space science: minimum 32 semester-hours of earth/space science, specializing in one area (astronomy, geology, meteorology, or oceanography), plus 16 semester-hours in other sciences. 4. General science: 8 semester-hours each in biology, chemistry, physics, earth/space science, and applications of science in society. Twelve hours in any one area, plus mathematics to at least the precalculus level. 5. Physical science: 24 semester-hours in chemistry, physics, and applications to society, plus 24 semester-hours in earth/space science; also an introductory biology course. 6. Physics: 32 semester-hours in physics, plus 16 in other sciences.

SOURCE: National Council of Teachers of Mathematics and the National Science Teachers Association

The national teaching force has good credentials; over so percent of all teachers now have at least a master's degree.[32] A 1985-86 survey found, in grades 10 to 12, that 63 percent of science teachers and 55 percent of mathematics

(continued from previous page)
room or to evaluate the outcomes of teaching through the progress made by students (which is becoming more common as States upgrade course requirements for high school graduation).

[32] National Education Association, ***Status of the American Public School Teacher 1985-86*** (West Haven, CT: 1987), tables 1-2.

teachers had earned degrees beyond the baccalaureate. The same survey also found that 40 percent of mathematics teachers had degrees in mathematics, and 60 percent of science teachers had degrees in a science field.” By contrast, only 1 to 2 percent of mathematics and science teachers at the elementary school level had degrees in these fields.

The National Survey of Science and Mathematics Education gathered its data from about **4,500** teachers from all grades in 1985-86.[34] The survey showed that many elementary mathematics and science teachers have taken very few college-level courses in these subjects, while secondary teachers of these subjects have much more extensive preparation. (See tables 3-4 and 3-5.)

The survey indicated that over 85 percent of elementary science teachers have taken at least one course in methods for teaching elementary school science, and about *90* percent have taken at least one college-level science course (typically biology, psychology, or physical science).[35] However, although **90** percent of elementary mathematics teachers have taken at least one course in methods for teaching mathematics, only about 40 percent have taken at least one college-level mathematics class. Most have taken instead mathematics courses especially designed for elementary mathematics teachers. Elementary school teachers feel good about mathematics; **99** percent feel well-qualified to teach it, compared to **64** percent who feel well-qualified to teach science, particularly physical science. About 80 percent of elementary mathematics and science teachers enjoy teaching these subjects. Inservice training is also not reaching many elementary teachers; more than 40 percent report that they have had no inservice training in the last year, and another **25** percent have had less than *6* hours in total during the year.

About **90** percent of junior high and high school mathematics and science teachers have taken at least introductory biology in college, over 70 percent have taken general physics, 50 percent geology, and 80 percent general chemistry. Many have specialized in biology and life sciences; few have specialized in physical sciences. About one-half have taken at least eight courses in life science, but only 14 percent of them have had eight courses in chemistry, and 10 percent eight courses in physics and earth sciences. As a group, over 90 percent of secondary science teachers enjoy teaching science, although 35 percent think that science is a difficult subject to learn.[36]

Table 3-4.—College-Level Courses Taken by Elementary and Secondary Mathematics Teachers

	Percentage of teachers with course[b]			
	Elementary		Secondary	
Course titles[a]	K-3	4-6	7-9	10-12
General Methods of Teaching	94	93	90	93
Methods of Teaching Elementary School Mathematics	90	90		
Methods of Teaching Middle School Mathematics	14	27	37	25
Methods of Teaching Secondary School Mathematics			53	80
Supervised Student Teaching	82	83	79	81
Psychology, Human Development	83	87	84	87
Mathematics for Elementary School Teachers	89	90		
Mathematics for Secondary School Teachers	11	21		
Geometry for Elementary or Middle School Teachers	17	21		
College Algebra, Trigonometry, Elementary Functions	30	37	***80***	***87***
Calculus	8	12	***67***	***89***
Advanced Calculus			***39***	***63***
Differential Equations			***39***	61
Geometry[c]	5	7	67	80
Probability and Statistics	21	27	59	76
Abstract Algebra/Number Theory			48	69
Linear Algebra			48	69
Applications of Mathematics/ Problem Solving			34	39
History of Mathematics			26	37
Other upper division mathematics			37	63
Sample N =	433	246	671	565

[a]Omits courses in computer programming and instructional uses of computers
[b]Empty cells mean data were not reported in original tabulation.
[c]Upper division geometry in case of elementary teachers

SOURCE: Iris R. Weiss, *Report of the 1985-88 National Survey of Science and Mathematics Education* (Research Triangle Park, NC: Research Triangle Institute, November 1987), tables 40, 44

[33]Weiss, op. cit., footnote 10, tables 38, 46.
[34]Ibid. For the higher grades, data are reported in two categories: teachers in grades *7* to *9* and grades 10 to 12; here they are summarized as averages for grades 7 to 12 combined.
[35]Ibid., tables *39-40.*
[36]Ibid., tables 41, 44.

Table 3-5.—College-Level Courses Taken by Elementary and Secondary Science Teachers

Course titles[a]	Percentage of teachers with course[b]			
	Elementary		Secondary	
	K-3	4-6	7-9	10-12
General Methods of Teaching	95	95	94	94
Methods of Teaching Elementary School Science	87	88		
Methods of Teaching Middle School Science	7	20	30	20
Methods of Teaching Secondary School Science			61	82
Supervised Student Teaching	77	87	83	79
Psychology, Human Development	83	88	85	87
Biology, Environmental, Life Sciences	83	87		
Chemistry	30	37		
Physics	17	21		
Physical Science	58	61		
Earth/Space Science	39	51		
No science courses	5	5		
Only one science course	18	12		
Two science courses	40	40		
Life Sciences:				
Introductory Biology			91	85
Botany, Plant Physiology			70	73
Cell Biology			54	58
Ecology, Environmental Sciences			62	63
Genetics, Evolution			55	64
Microbiology			48	53
Physiology			63	65
Zoology, Animal Behavior			64	71
Chemistry:				
General Chemistry			76	92
Analytical Chemistry			30	47
Organic Chemistry			51	
Physical Chemistry			21	32
Biochemistry			25	34
Physics:				
General Physics			73	81
Electricity and Magnetism			18	28
Heat and Thermodynamics			16	24
Mechanics			15	26
Modern or Nuclear Physics			12	23
Optics			11	18
Earth/Space Sciences:				
Astronomy			40	36
Geology			56	49
Meteorology			27	20
Oceanography			26	19
Physical Geography			39	25
Other:				
History of Science			21	23
Science and Society			18	16
Engineering			8	12
Sample N =	431	273	658	1,050

[a]Omits courses in computer programming and instructional uses of computers
[b]Empty cells mean data were not reported in original tabulation

SOURCE: Iris R Weiss, *Report of the 1985-86 National Survey of Science and Mathematics Education* (Research Triangle Park, NC: Research Triangle Institute, November 1987), tables 39 and 41

Of mathematics teachers in grades 7 to 12, over 80 percent have had at least college algebra, trigonometry, or elementary functions, and about 70 percent of them have had calculus. Still, about 7 percent feel inadequately qualified to teach mathematics, and over 25 percent had not taken a college course for credit in the last 12 years (55 percent during the last 5 years). Over **50** percent have not had more than **6** hours of inservice education during the last year. This translates into a lack of confidence in teaching skills. About 20 percent of elementary teachers felt very well-qualified to teach mathematics and science respectively; another 20 percent felt they were not well-qualified to teach science.[37]

Options for Improving the Quality of Mathematics and Science Teachers

More States indicate shortages of ***quality*** science and mathematics teachers than of teachers with appropriate qualifications to teach these subjects. Credentials are not enough. Most States have attempted to alleviate their shortages through higher teacher salaries, and some also use special loan and staff development programs for mathematics and science teachers in order to retain good teachers and retrain teachers from other fields. Iowa, for example, grants loans to current teachers to upgrade their skills in mathematics and science teaching, and sponsors summer training institutes. Idaho uses Title II funds to provide scholarships to potential science or mathematics teachers who want to be recertified in these subject areas.

At least **26** States have inservice teacher training programs for science and mathematics instructors, most involving loans or scholarships to promote additional coursework. The Teacher Summer Business Training and Employment Program in New York partly reimburses industry for science, mathematics, computer, or occupational education teachers employed by business and industry during the summer. In Kentucky, Title II funds support the Science Improvement Project in low-income districts with histories of low achievement,

[37]See National Science Board, op. cit., footnote ***6,*** pp. 27-28.

About 10 States now offer alternative certification programs for prospective mathematics and science teachers. For example, Utah awards "Eminence Certificates" to qualified professionals such as engineers and doctors, which allows them to teach up to two classes per day. Other, more innovative means of recruiting new mathematics and science teachers include hiring teachers from overseas. (California and Georgia recruit science and mathematics teachers from the Federal Republic of Germany, and Kansas City, Missouri, has imported teachers from Belgium.) Florida holds an intensive teacher job fair each June, called "The Great Florida Teach-In, " designed to attract and place new teachers.

The quality of the mathematics and science teacher work forces can be improved before people enter the classroom as teachers (generally referred to as preservice) or when they are actively teaching (inservice). Given the low labor turnover of the teaching force, between 5 and 10 percent each year in all subjects,[38] the way to upgrade teaching quality is via inservice programs. Yet there is considerable national anxiety about the perceived deficiencies of preservice teacher preparation in all disciplines .39

Preservice Education

While many talented people do become teachers, it is sometimes suggested that teacher education is not challenging.[40] Critics further charge that teacher preparation programs fail to make effective links between courses on mathematics and science and those on education, and therefore, teachers are unable to convert courses on classroom teaching techniques and theories of learning. In addition, such courses convey a simplistic view of science as a monolithic collection of facts, embodied in enormous textbooks, giving students a false impression of the nature of scientific inquiry.

Teachers agree that experiments and hands-on activities are more effective than book work, but feel the overriding need to cover material in encyclopedic fashion. The extensive use of factual recall tests creates incentives to cover the content, rather than process, of the subject matter. Thus, teacher preparation may be more telling than their classroom practice. In college, prospective teachers model their attitudes and teaching practices on those of their college professors and, indeed, on their own school teachers. They employ the teaching techniques, such as lectures and rote memorization, that they were either forced to suffer or benefited from when they were students. School district curriculum guides and testing fuel teachers' reliance on tools for covering concepts and facts, one by one, without drawing links and brightening the big picture of science. Preference may signal a lack of alternatives; teachers may have neither the tools nor the opportunity to become comfortable with them to change their approach.

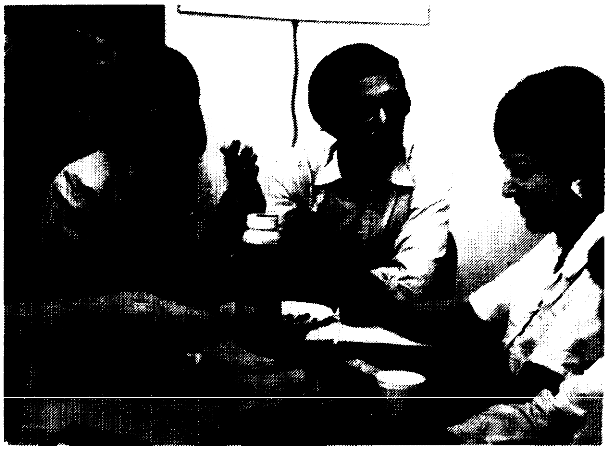


Photo credit: William Mills, Montgomery County Public Schools

Most reports on reforming education single out the importance of improving the status, appeal, and quality of the teaching profession.

[38]National Education Association, op. cit., footnote 32, table 13; Blake Rodman, "Attrition Rate for Teachers Hits 25-Year Low, Study Finds, " *Education Week,* Oct. 14, 1987, p. 8.

[39]For an overview, see Frank Ambrosie and Paul W. Haley, "The Changing School Climate and Teacher Professionalization," *NASSP [National Association of Secondary School Principals] Bulletin, vol. 72,* January 1988, pp. 82-89. The following two sections are based in part on Iris R. Weiss, OTA Workshop on Mathematics and Science Education K-12: Teachers and the Future, Summary Report, September *1987.*

[40]National Science Board, op. cit., footnote *6,* p. *25.* As Bernard R. Gifford, Dean of the School of Education, University of California-Berkeley, puts it: "What's wrong with schools and departments of education today is very simple. Education suffers from congenital prestige deprivation. " See Anne C. Roark, "The Ghetto of Academe: Few Takers (Teacher Colleges)," Los *Angeles Times,* Mar. 13, 1988, p. 6. A new book dissects the origins and repercussions of this prestige deprivation on university campuses. See Geraldine Joncich Clifford and James W. Guthrie, *Ed School. A Brief for Professional Education* (Chicago, IL: University of Chicago Press, 1988).

There is still no complete model of what the mathematics and science teacher curriculum should be. Simply requiring more mathematics and science courses for certification will not automatically improve teacher quality, given the content of these courses and the way they are often taught. The National Science Foundation (NSF), for example, has recently begun a program to develop new models for preservice preparation of middle school teachers.

One particular controversy in mathematics and science teacher education is whether future teachers should be expected to have a baccalaureate degree in a discipline plus some professional training. At present, many teachers at the elementary level earn baccalaureate degrees in education, but 97 percent of elementary mathematics teachers and 95 percent of elementary science teachers have a degree in subjects other than science or science education. At the high school level, however, 40 percent of mathematics teachers and 60 percent of science teachers have a degree in those subjects, and another *36* and **24** percent, respectively, have a degree in mathematics and science education or a joint degree in a mathematics and science subject and science and mathematics education .41

Several groups that have studied the future of the teaching profession in the current reform movement have looked at this issue. The Holmes Group (an informal consortium of education deans in research universities) has attached priority to upgrading elementary and secondary teachers' specific knowledge by insisting that they have a baccalaureate degree in a subject area. The Holmes Group has also called for much greater use of specialized teaching, and for more subject-intensive preparation of those teachers.[42] So far, only Texas has changed its certification requirements in this way; after 1991, new entrants to the profession in Texas will have to have both a disciplinary degree and no more than *18* course-hours of education courses.[43]

Currently, NSTA and NCTM both require considerable amounts of subject-specific coursework of applicants for their own certification programs. Content, rather than titles, of the courses future teachers take is essential; there is a large grey area that colleges and universities can exploit in specific subject areas (such as mathematics education). But the long-term trend is to emphasize specific skills for specific subjects rather than generic "education" courses.

Preservice education of science and mathematics teachers presents a surfeit of issues and little consensus over how to address them. College departments of science and mathematics prepare their students to become scientists or engineers, not teachers of these subjects. Few, if any, courses are offered that give prospective teachers a sense of what scientists do or how science and mathematics impact on workday activities and societal problems. Can teachers be blamed for not taking what is not offered, or for not executing in their classrooms what they were unable to experience as students (i.e., the apprenticeship role)? This "no-fault" explanation distributes the responsibility for the perceived shortcomings of the neophyte teacher.[44] It also transfers part of the burden to inservice training.

The Importance of Inservice Training

Once teachers are in place, as in any professional work force, they need periodic updating and time to consider how they could do their jobs better. At present, inservice training is also needed to remedy the inadequacies of many teachers' preservice preparation. A recent survey indicates that there has been an increase in the amount of inservice training taken during the school year, which has come at the expense of college-level

"Weiss, op. cit., footnote 10, table 45.

'*The Holmes Group, ***Tomorrow's Teachers*** (East Lansing, MI: 1986). See also Lynn Olson, "An Overview of the Holmes Group, " ***Phi Delta Kappan***, April 1987, pp. 619-621. Subject-intensive preparation may be unrealistic for elementary school teachers. Just ask an elementary teacher what she teaches and the response will be "children" or "grade n"; a secondary school teacher will respond with "science" or "math. " Most parents would probably take comfort that their child is being taught by someone who believes their primary allegiance and responsibility is to children, not subjects (Shirley Malcom, American Association for the Advancement of Science, personal communication, August ***1988).***

[43]Lynn Olson, "Texas Teacher Educators in Turmoil Over Reform Law's 'Encroachment'," ***Education Week,*** vol. ***7,*** No. 14, Dec. 9, 1987, p. 1.

[44]1f scientists want to prescribe what science is worth knowing, they must be willing to collaborate with teachers in deciding what science is worth teaching. When should phenomena just be experienced and the underlying scientific principles withheld? Such a question beckons to an interdisciplinary team of scientists, teachers, child development specialists, and psychologists for answers.

course-taking on weekends and during vacations. Three-quarters of teachers now report taking in-service courses during the school year, compared with 59 percent 15 years ago,[45]

Another recent survey found that most mathematics and science teachers, at all grade levels, had spent less than 6 hours on inservice education in 1984. (See figure 3-3.) Secondary teachers had spent more time on inservice education than elementary teachers; over 10 percent of mathematics and science teachers in grades 10 to **12** had taken more than 35 hours of inservice education during the last year.”

A leading policy issue is who should be responsible for inservice education. As employers, school districts should be primary supporters of such education, but it is among the first budget items to be cut in periods of austerity. In practice, teachers are often expected to arrange and pay for such education themselves. While many teachers do participate, commentators suggest that there is a large pool of mathematics and science teachers who are never reached.[47]

Perhaps most lacking is a national commitment to the continuing education of science and mathematics teachers. Such education comes in many forms, including multiweek full-time summer institutes, occasional days to attend professional meetings, and provision of relevant research materials and work sessions on how to translate these into practice. In some areas, contacts between schools, school districts, scientific societies, State education agencies, and universities exist and are fruitful, but other areas are devoid of this support. Teachers need much better information than they are getting, particularly because of rapid changes in science and educational technology. ’s

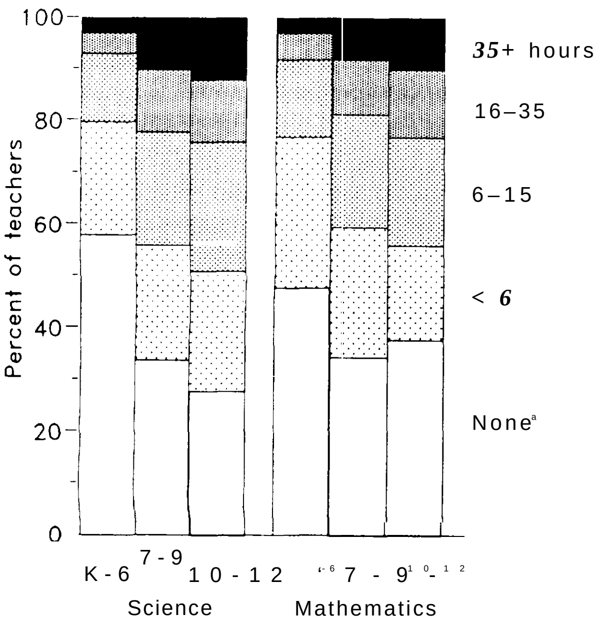
The Federal Government supports inservice teacher education through both Title II of the Education for Economic Security Act program of the Department of Education and the NSF Teacher Enhancement Program. In the 1960s, NSF funded a large program of summer and other institutes, based at universities, for mathematics and science teachers. (See ch. ***6.)*** Generally, these institutes seemed to have had positive effects, and their perceived excesses (for example, an emphasis on knowledge of science content) could be reduced were the concept to be revived. The bulk of the funds in the previous program went to colleges and universities; local school districts could now be partners in such education.

Another important Federal role could be a regional system of mathematics and science educa-

[45]National Education Association, op. cit., footnote 32, tables 44-4.5.

[46]Weiss, op. cit., foonote 10, table 56. This difference in inservice education time may simpl, reflect greater opportunity afforded secondary school teachers, not lesser interest on the part of elementary teachers,

Figure 3-3.—Amount of Inservice Training Received by Science and Mathematics Teachers During 1985-86



[a]Includes about 10 percent with unknown time.

NOTE’ Science and mathematics teachers were asked how much inservice train. ing in science they received m the past 12 months. Inservice training includes attendance at professional meetings and workshops, but not formal courses for college credit Sample sizes range from about 560 to 1,050, varying with grade level and field

SOURCE Iris R Weiss, *Report of the* 1985-86 *National Survey of Science and Mathematics Education* (Research Triangle Park, NC Research Triangle Institute November 1987), p 92

[47]This explanation raises the issue of incentives. For what does an elementary school teacher get “credit”? How do teachers perceive the relative priorities of different subject areas, e.g., language arts v. mathematics?

[48]A recent proposal is for 8 to 10 federally funded science education centers, spread around the country, which would develop curricula, train teachers, set up networks, and conduct research. See Myron J. Atkin, “Education at the National Science Foundation—Historical Perspectives, An Assessment, and A Proposed Initiative for ***1989*** and Beyond, ” testimony before the House Subcommittee on Science, Research, and Technology of the Committee on Science, Space, and Technology, Mar. 22, 1988, pp. 14-17.

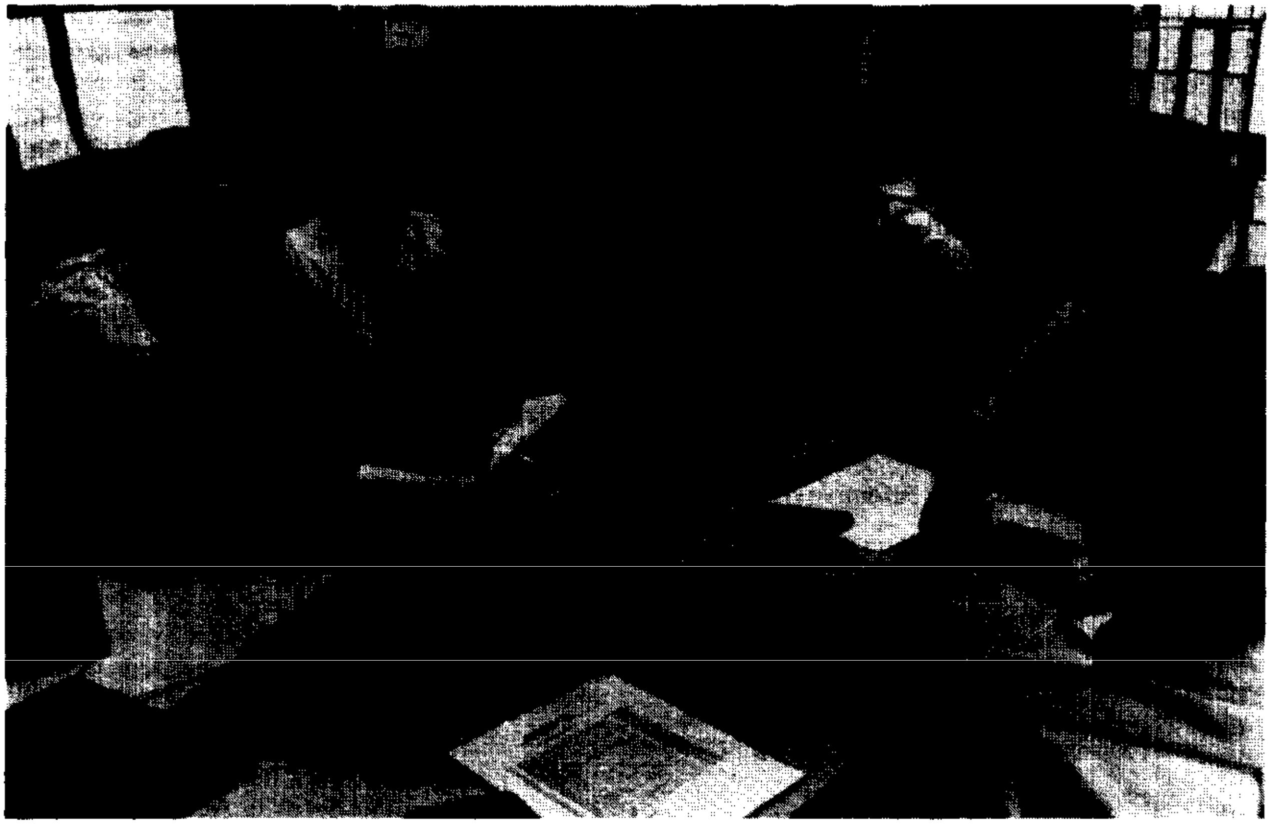


Photo credit: Lawrence Hall of Science

Teacher training, important in keeping teachers up-to-date and motivated, has been a significant Federal role.

tion advisors. School administrators need training, too; they would work with school districts in disseminating the results of (at least federally sponsored) educational research, and affecting classroom practice. This role would be similar to that of county Agricultural Extension agents. The National Diffusion Network, currently restricted to conveying effective teaching curricula, is an existing mechanism for disseminating research information. Finally, the Federal Government might assist in linking teachers through informal meetings and electronic message networks. The State supervisors of science are already planning such a network.

Conclusions on Mathematics and Science Teacher Quality

The effect that good mathematics and science teaching has on students' propensity to major in science and engineering is not readily measured. Schools must lead, inform, and interest students in mathematics and science, and teachers are the front line. At the moment, many only inform and some probably dull students' interest in mathematics and science. On paper, the teaching profession is relatively well-qualified, and has had a significant (and increasing) amount of teaching experience. The teaching force needs inservice education, however; this presents an enormous task. School districts, States, and teachers (who have already had and paid for a college education) are unlikely to undertake this alone. Until school districts and States make mathematics and science teacher quality a high priority, student interest in and preparation for careers in science and engineering are not likely to flourish.

TEACHING PRACTICES AND STUDENT LEARNING

There are several teaching techniques that could be used more widely to boost both students' learning and interest in mathematics and science. In recent years, a considerable body of literature on "effective schools" has been assembled. This research has been synthesized for teachers, principals, and administrators to read.[49] There is an urgent need to write and disseminate more syntheses of this kind in other educational research areas.[50]

One technique in both mathematics and science education is experimentation. Experiments, especially when they are related to physical phenomena that students encounter in everyday life, are widely credited with improving students' attitudes toward and achievement in science. According to a recent survey, teachers think that hands-on science is an effective teaching method, yet few use it.[51] If experiments are properly planned, students learn that science advances by curiosity, manipulation, and failure. Mistakes are a normal part of science. The use of textbooks that emphasize the "facts" discovered by science, on the other hand, reinforces the popular (but mythical) view that science is a logical, linear process of accumulating knowledge.

Science experiments raise achievement scores and can often trigger positive attitudes toward science among students. Nevertheless, concerns about the cost and safety of experiments inhibit the amount of laboratory work offered, as do the limited facilities many schools have for this kind of teaching. Experiments require equipment and are more costly than lectures.[52]

Indications are that the amount of hands-on mathematics and experimental science is diminishing. (See figure 3-4.) A recent survey found that the percentage of science classes in 1985-86 using hands-on activities has fallen somewhat since 1977 at all grade levels. Hands-on activities were most common in elementary classes; only *39* percent of science classes in grades 10 to 12 used the technique (down from 53 percent in 1977). In mathematics, there have been similar declines, with the sole exception of an increase in the use of hands-on techniques in grades K-3.[53]

Other proposed teaching practices that might improve mathematics and science instruction include the use of open-ended class discussions, small group learning, and the introduction of topics concerning the social uses and implications of science and technology (often called science, technology, and society, or STS). In particular,

[49] Northwest Regional Educational Laboratory, ***Effective Schooling Practices: A Research Synthesis*** (Portland, OR: April 1984); and James B. Stedman, Congressional Research Service, "The Effective Schools Research: Content and Criticisms, " 85-1122 EPW, unpublished manuscript, December 1985. Becoming aware of, reading about, and knowing how to apply the lessons learned, of course, are very different (Audrey Champagne, American Association for the Advancement of Science, personal communication, August 1988),

[50] In the case of mathematics and science education, the federally funded ERIC Clearinghouse for Science, Mathematics, and Environmental Education issues quarterly and annual reviews of research designed for practitioners rather than researchers. The National Association for Research in Science Teaching (NARST) also compiles summaries of current research applications in science education. The NARST series is titled ***Research Matters . . . To the Science Teacher,*** and is published on an occasional basis through Dr. Glenn Markle, 401 Teacher College, University of Cincinnati, Cincinnati, OH 45221. The ERIC series is a set of regular research digests in mathematics, science, and environmental education, published by the ERIC Clearinghouse for Science, Mathematics, and Environmental Education, 1200 Chambers Rd., Columbus, OH 43212. See, for example, Patricia E. Blosser, "Meta-Analysis Research on Science Education, " *ERIC/SMEAC* ***Science Education Digest, No.*** 1, 1985. Finally, an ongoing project conducted by the Cosmos Corp., in collaboration with several educational associations and funded by the National Science Foundation, is collecting data on exemplary mathematics and science curriculum and teaching practices for dissemination nationally. See J. Lynne White (cd.), ***Catalogue of Practices in Science and Mathematics Education*** (Washington, DC: Cosmos Corp., June **1986).**

[51] Eighty percent of high school science teachers agree that laboratory-based science classes are more effective than lecture-based classes, while only about 40 percent reported that they had used the technique in their most recent lesson. Weiss, op. cit., footnote 10, tables **25, 28.**

[52] Indeed, experiments are a logistical nightmare for many schools: It takes teacher's valuable time to set up and tear down laboratories, assemble materials and equipment, take safety precautions, cue teacher's aides, etc. The costs—financial and otherwise—to run an experiment are often seen as prohibitive.

[53] Weiss, op. cit., footnote 10, table **25;** Robert Rothman, "Hands-On Science Instruction Declining, " ***Education Week,*** Mar. 9, 1988, p. 4. Data from the 1985-86 National Assessment of Educational Progress show that 78 percent of grade 7 students and 82 percent of grade 11 students report "never" having laboratory activities in mathematics classes. Nineteen and **15** percent of students in these grades, respectively, reported having laboratory activities either weekly or less than weekly. See John A. Dossey et al., ***The Mathematics Report Card: Are We Measuring Up? Trends and Achievement Based on the 1986 National Assessment*** (Princeton, NJ: Educational Testing Service, June ***1988),*** p. **75.**

Photo credit: William Mills, Montgomery County Public Schools

Hands-on science projects can be both fun and educational, and do not always require expensive equipment.

the practice of dividing classes into small, mixed-ability groups of five or six students to work on problems collectively, rather than solve them by individual competition, is widely practiced in elementary schools in Japan and is reported to be effective for students of all abilities. Its use is increasingly being advocated for the United States. The newly approved elementary mathematics curriculum in California is designed for the use of this technique, in anticipation of its wider application." A recent survey found that over one-half of all students never did mathematics in small groups; only **12** percent of 3rd graders, ***6*** percent of 7th graders, and 7 percent of 11th graders reported using this technique daily. The survey concluded:

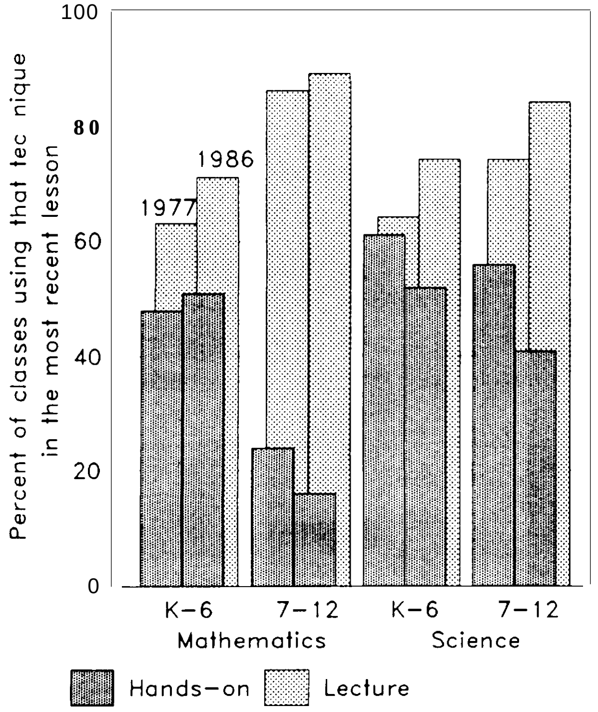
> Instruction in mathematics classes is characterized by teachers explaining material, working problems on the board, and having students work mathematics problems on their own. . , .
>
> Considering the prevalence of research suggesting that there may be better ways for students to learn mathematics than by listening to their teachers and then practicing what they have heard in rote fashion, the rarity of innovative instructional approaches is a matter for true concern .55

Because so few of these new practices are used, too many of the Nation's mathematics and science high school classes consist of teachers lec-

[54]Roger T. Johnson and David W. Johnson, "Cooperative Learning and the Achievement and Socialization Crises in Science and Mathematics Classrooms, " ***Students and Science Learning: Papers From the 1987 National Forum for School Science,*** Audrey B. Champagne and Leslie E. Homig (eds.) (Washington, DC: American Association for the Advancement of Science, 1987), pp. 67-94; and Robert E. Slavin, ***Cooperative Learning: Student Teams*** (Washington, DC: National Education Association, March 1987).

[55]Dossey et al., op. cit., foonote ***53,*** pp. ***74-76.***

Figure 3-4.— Percentage of Mathematics and Science Classes Using Hands-on Teaching and Lecture, 1977 and 1985.86



SOURCE: Iris R Weiss, *Report of the 1985-86 National Survey of Science and Mathematics Education* (Research Triangle Park, NC: Research Triangle Institute, November 1987), p 49.

turing about abstract material directly from textbooks, Research on teaching practices and student learning indicates that if teaching were better oriented to the way students learn, and took account of how they fit classroom knowledge into their often inaccurate world views (culled from a variety of sources), students would likely learn more and "better. "[56]

Pleas for attentiveness to individual needs and learning styles possessed by different students should not be mistaken for a solution to the problems set forth in this chapter. Mathematics and science teachers are one pivotal working part in the social system known as "school. "

[56] Sometimes a simple change of procedure can make a world of difference. Anne Arundel County, MD, is hoping for just such marked results, announcing its intentions of assigning the "best" teachers to students most in educational need. Will teacher assignment alone change the educational experience? Similarly, will the promotion of "master teachers" upgrade the classroom performance of teachers and students? These are school experiments intended to change the fit of the pieces in the learning puzzle.