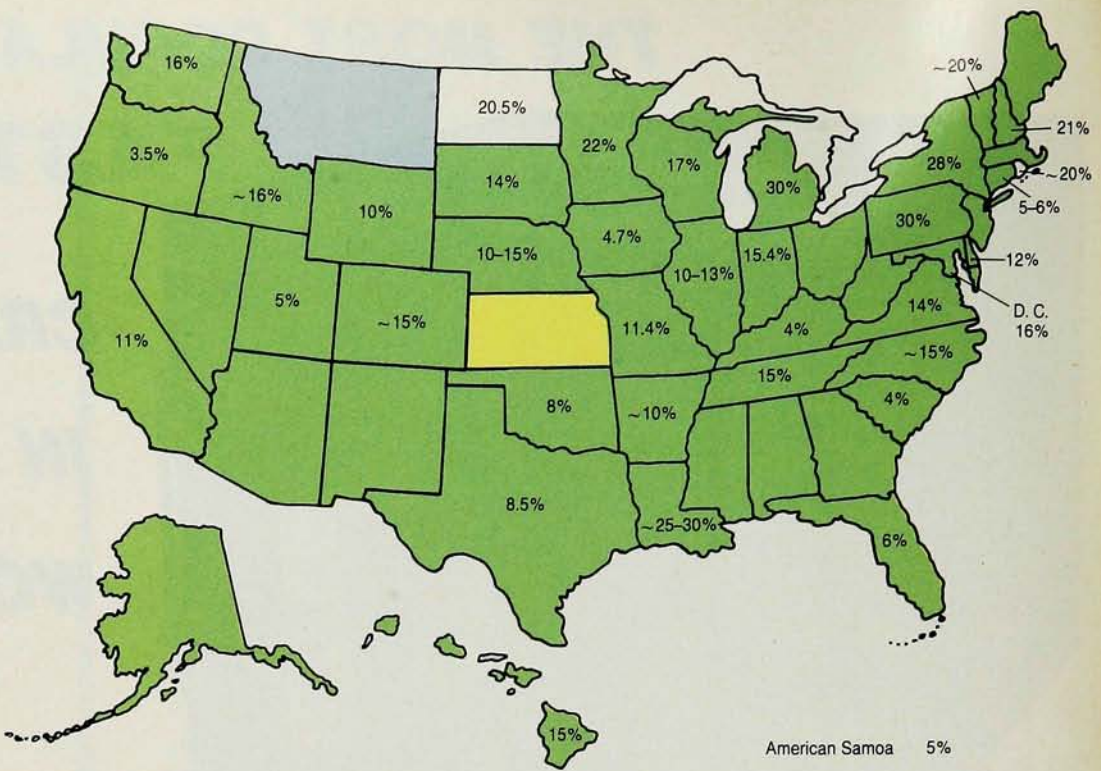

Shortages of physics teachers and mathematics teachers in the US, 1983. States with shortages of physics teachers are shown in blue, those with shortages of mathematics teachers in yellow, and those with shortages of both mathematics and physics teachers in green. The percentages of graduating seniors who took physics are indicated where this information was available.

High-school physics: Progress and continuing challenge

Local, state and national initiatives may have helped to improve precollege teaching and to make the career of science teacher more attractive, but a survey shows that much remains to be done.

Robert Beck Clark

In September 1983, PHYSICS TODAY devoted a special issue to the crisis in US high-school physics education. That issue was prepared in the wake of a series of well-publicized reports[1] from a number of prominent national commissions and committees that documented the severity of the crisis. Of particular interest to the physics community was the shortage of qualified high-school physics instructors across the nation and the low level of high-school physics enrollment.

The article "Paths to a solution" in that issue (page 44) summarized a number of specific reforms deemed vital for reducing the shortage of qualified teachers:

- ▶ improve financial compensation for science teachers
- ▶ reexamine state certification requirements
- ▶ provide appropriate pre- and in-service training
- ▶ institute methods for recognizing effective teachers.

To remedy the associated problem of low high-school physics enrollments, the article recommended the following:

- ▶ provide adequate equipment and outside sup-

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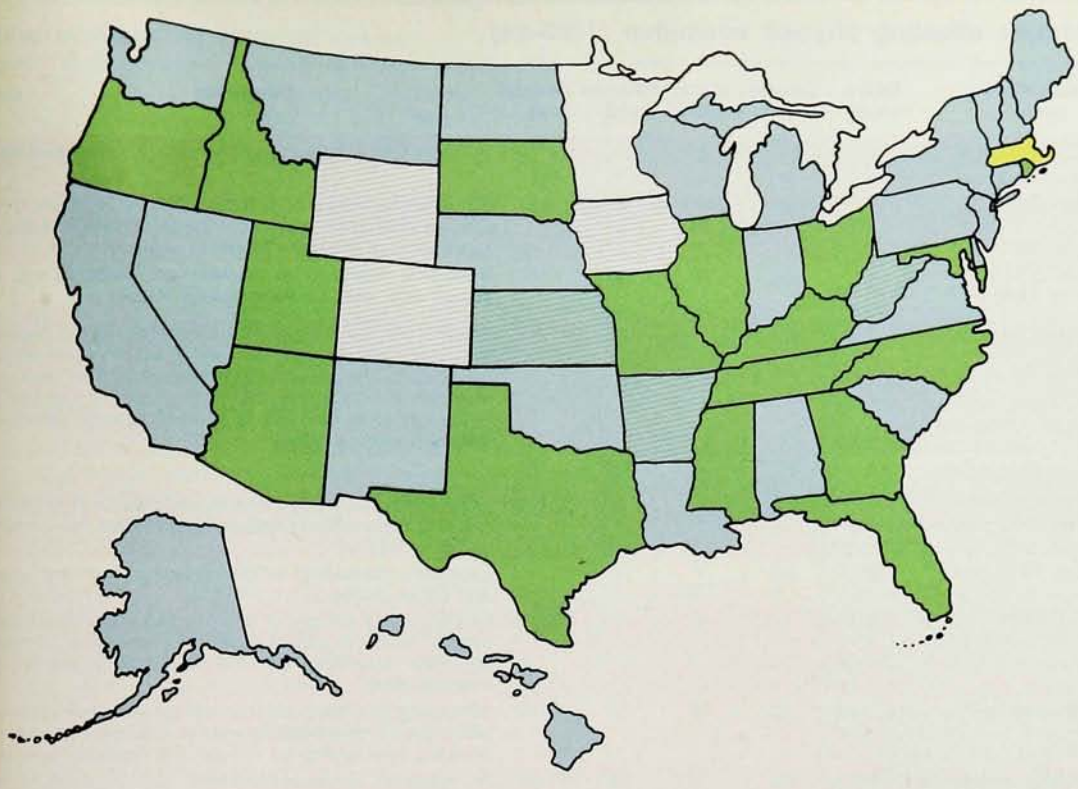

Tougher requirements in science and mathematics for high-school graduation and increased college-admission standards in the US. States that have increased high-school requirements are shown in blue and those that have increased college standards in yellow. States that have increased both are shown in green. Stripes indicate states that are considering these increases.

port to help teachers increase the excitement and interest of science classes

- ▶ raise high-school graduation requirements
- ▶ raise college entrance requirements
- ▶ establish programs to attract female and minority students to the physics classroom.

Because state and local authorities are responsible for precollege education in the United States, these reforms necessarily require the individual actions of the 50 state legislatures and more than 17 000 school boards. The Federal government, however, can provide strong leadership and financial support.

Two years have now passed. How do we stand? The good news is that there has been measurable progress at both the Federal and the state level.

Let us look at just what has been accomplished. The positive steps taken by the Federal government in restoring funding for precollege science and mathematics education have been described previously.[2] The past two summers have seen science and mathematics teachers returning to a variety of excellent programs across the country designed to provide much-needed basic training and enrichment. These programs are particularly valuable for teachers who work in relative isolation as the only physics teacher in a school. The value of providing these teachers with the opportunity to share new ideas and techniques with other highly motivated teachers cannot be underestimated.

One workshop participant, a veteran of the high-school physics classroom, undoubtedly spoke for others when he discussed the impact that a recent NSF summer workshop had had on him. He explained that the past year had been something of a low point in his teaching career. The administration of his school had changed, discipline had suffered and student morale (and his) had reached an ebb. Then came summer and the workshop. After only a few days of participation in the workshop, he could, as he expressed it, feel his "batteries start to recharge once again." By the time the workshop was over he could hardly wait to get back to his classroom to try out some of the new ideas with his students.

Federal, state and local programs

The NSF-supported programs for high-school physics teachers are alive again and working. Unfortunately, the currently available funding limits participation to only a fraction of the active high-school physics teachers. The proposed 1986 NSF science-education budget[3] cuts the $82 million of new funds available in 1985 to only $50 million. The problem is compounded by the decrease in the percentage of the budget that is available for high-school programs as the much-needed programs for kindergarten through eighth grade gain emphasis at NSF. Further reductions may be necessary to provide for the urgent need for NSF support of undergraduate education.[4]

Congress has appropriated an additional $100 million for 1985 for precollege science education through the US Department of Education.[5] The majority of these funds ($90 million) are to be disseminated through block grants to the states. Of this amount 70% ($63 million) is earmarked for instructional materials or training of elementary- and secondary-school teachers in mathematics, sciences, foreign languages and computers. The remaining $10 million is to be awarded by the Secretary of Education for projects in science and mathematics education. The impact of these funds on precollege physics education is much more difficult to predict. Those who desire to influence the eventual use of these funds in their areas may wish to contact their state department of education and ask about the particular plans for their state's Federal science-education block grant.

How have we done at the state and local level? It is still difficult to obtain and summarize information regarding reforms at the local-district level because of the large number of districts involved. However, information regarding reform initiatives at the state level is now becoming available. An excellent summary[6] of state actions over the past two years (1983–84) was published in *Education Week*. The article was prepared under the direction of Joanne Tarr, who is on the staff

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State educational reforms affecting physics education (1983–84)

State	Minimum starting salary	Salary raised*	Career ladder†	Coll. bargain.‡	Financial aid§	Revised cert.**	Comments
Alabama	$20 000/10 months	Y	UC	N	Y	Y	Extracurricular activities during school day curtailed (1984).
Alaska	No minimum	N	N	Y	Y	UC	
Arizona	By district	UC	UC	N	Y	UC	Scholarships approved for gifted high-school students to attend summer math and science programs (1983). Minimum salary level of $18 000/10 months proposed.
Arkansas	$12 000 to $15 000 per 12 months	Y	UC	N	UC	UC	Basic-skills testing for all teachers, and academic skills in subject area must be demonstrated (1983).
California	$18 000/9 months	Y	Y	Y	Y	Y	Phase-in of a new salary schedule is due in 1986–87. Districts with shortages may hire noncertified teachers with BA in subject area, who must pass basic-skills and subject tests and work with a mentor teacher (1983). New high schools in specialized fields; funds for nonremedial summer schools in math and science (1984).
Colorado	No statewide minimum	N	UC	Y	UC	UC	
Connecticut	$10 819 to $17 794 per 180 class days	UC	UC	Y	Y	UC	Governor's Commission on Equity and Excellence in Education is considering a recommendation to raise the minimum salary to $18 500.
Delaware	$13 500/10 months	UC	UC	Y	Y	Y	Legislature considering $1000 increase in beginning salary and career ladder.
Florida	Varies	Y	Y	Y	Y	Y	Salaries raised average of $2000 in 1984–85. Three years each of math and science required for graduation. Schools may hire noncertified teachers with doctoral degrees in shortage fields.
Georgia	$18 000 + /10 months	Y	UC	N	Y	UC	10% salary increase (1984). Precollege education has been restructured by a new education law (Quality Basic Education), providing new funding for science and increased salaries.
Hawaii	$16 000/10 months	N	UC	Y	UC	UC	No significant steps toward reform.
Idaho	$14 000/9 months	Y	Y	Y	N	Y	Second year of career-ladder and merit-pay program not funded by the legislature.
Illinois	Each district sets salaries	UC	Y	Y	Y	UC	Legislature appropriated funds for a master-teacher program (1983). Proposal to limit extracurricular activities is under consideration. Demand for physics teachers is low.
Indiana	Approx. $15 000/9 months	N	UC	N	Y	Y	Tax-incentive programs for businesses and industries employing teachers in summer (1983). Programs for gifted students expanded (1984). Subject-area test for new and out-of-state teachers (1985).
Iowa	$13 500/10 months, state average	UC	UC	Y	Y	Y	Proposed legislation could have significant effect on salaries, career ladder, certification standards and competency testing.
Kansas	By district	Y	Y	Y	N	Y	9.75 and 10% salary increases in 1984 and 1985, respectively.
Kentucky	$13 000/9¼ months	N	UC	N	Y	Y	Governor preparing educational-reform package for 1986 legislature.
Louisiana	$14 500/9 months	Y	UC	N	Y	Y	Raised high-school graduation requirements to 3 years each of math and science (1989). Legislature raised admission standards at Louisiana State University to require specific preliminary course work in high school.
Maine	NA	Y	Y	Y	Y	Y	$2000 across-board bonuses (1984). Upgrading of certification to 3 levels of certificates, leading to master teacher (passed 1984, to be implemented 1988).
Maryland	By county	UC	N	N	Y	N	No major educational-reform initiatives expected in 1985.
Massachusetts	Varies, salaries set locally	N	UC	Y	N	N	"Horace Mann" teacher bonuses being debated by legislature; omnibus education-reform bill rejected in 1984 because of high cost.
Michigan	Varies	UC	N	Y	N	UC	Because economy has improved, legislature may approve more funds for education.
Minnesota	$15 000/10 months	UC	UC	Y	N	UC	Average salary in Minneapolis suburbs has been raised to over $30 000. Physics-teacher shortage is not serious.
Mississippi	NA	Y	N	N	N	UC	State revenue situation tight. Proposed school consolidation and salary increases are very controversial issues.
Missouri	$15 000/9 months starting July 1986, then $16 000 (1987), $17 000 (1988) and $18 000 (1989)	UC	UC	N	UC	Y	The state board has proposed establishment of a minimum salary of $17 000. In-service institutes in math and science established (1983). Summer institutes for gifted juniors (1985).
Montana	District negotiated	N	N	N	UC	Y	The Montana University system has adopted preparatory program that is taken very seriously by local school districts.
Nebraska	By district	UC	Y	Y	Y	N	Omnibus education-reform bill passed in 1984, but not funded. Financial support for farm relief will probably take precedence.
Nevada	$12 000 + /10 months, determined by system	UC	N	Y	UC	Y	Governor and state board proposed salary increase to attract better teachers (1985). Provisional certification approved for qualified individuals with incomplete training (1984).
New Hampshire	$9650 to $14 169	N	UC	Y	UC	Y	Pilot summer program for gifted students funded by governor (1984). State board has urged districts to provide professionally competitive salaries (1984).

State educational reforms *continued*

State	Minimum starting salary	Salary raised*	Career ladder†	Coll. bargain.‡	Financial aid§	Revised cert.**	Comments
New Jersey	No minimum	UC	Y	Y	UC	Y	Master-teacher pilot program to award $5000 to top 5% of teachers in 10 districts (1984). Alternative certification program approved and implemented (1984). Funds allocated for summer institutes for math and science teachers (1985).
New Mexico	By district	UC	UC	Y	N	Y	Governor proposed increasing starting salaries to $25 000 by 1989. Legislature to consider increased salaries and merit pay. State in poor fiscal health.
New York	Set by each school district	UC	UC	Y	Y	Y	Increased high-school graduation requirements went into effect September 1985. Students seeking State Regents diploma with sequence in science are more likely to take physics.
North Carolina	$15 030/10 months	Y	UC	N	Y	Y	A new, more comprehensive statewide curriculum offering a choice of "academic" or "technical" physics courses will be implemented in 1985–86.
North Dakota	No state minimum	N	N	N	N	N	High priority for education by governor, but money is fairly tight and it will be up to the legislature to raise necessary revenues.
Ohio	$12 000/9 months	UC	UC	Y	UC	UC	Legislature has raised income tax to restore education funds previously cut. Governor has endorsed income-tax cuts. Only one unit of science required for graduation.
Oklahoma	$12 060/9 months	Y	N	N	N	Y	Controversy over funding for educational reform. Considerable revision in certification, establishing exit exams and mentor program for first-year teachers.
Oregon	$13 089 to $16 700 per 9.5 months	N	N	Y	N	UC	Governor has proposed sales tax to fund "Basic Education" plan.
Pennsylvania	$11 500/9 months, varies in local districts	N	UC	Y	Y	Y	Three math and three science credits required for graduation. Governor's school for the sciences established. "Turning the Tide" reform package, $86 million.
Rhode Island	$14 500/180 days, state average	N	N	Y	N	Y	Basic education program defining curriculum standards mandated by the board of regents (1985). Merit pay being investigated in the Burrillville district.
South Carolina	$14 675/185 class days	Y	Y	N	Y	Y	Legislature appropriated $60 million to bring salaries up to southeastern average in 1985 and established incentive program for superior performance. Allows provisional contracts for holders of BS or BA in physics (1984).
South Dakota	NA	N	UC	N	N	Y	Established regents-scholar program: special diploma for a 3.0 grade average and 4 credits in English, math, science, 3 in social studies and 2 in foreign language (1984).
Tennessee	$13 455/10 months	Y	Y	Y	Y	Y	Five-step career ladder, annual incentives of $5000–7000 and 11- or 12-month contracts for master teachers (1984). Appropriated $450 000 for high-school lab equipment (1984).
Texas	$15 200/10 months	Y	Y	N	Y	Y	Three-level career ladder implemented. "No pass, no play" rule approved and only 5 extracurricular absences allowed per semester. Alternative certification plan approved for holders of BS and BA with no college education courses (1984).
Utah	$15 000/9 months	UC	Y	Y	Y	N	Legislature is expected to increase funds for education, but reform is now on back burner.
Vermont	$12 000/10 months, but varies according to contract in individual districts	N	N	Y	Y	Y	Graduation requirements increased to 3 years each of math and science. Governor has proposed 8-cent cigarette-tax increase for education.
Virginia	NA, $18 535 state average for all teachers	Y	UC	N	Y	Y	Three years of math and science required for college-prep students (1984). Pilot project of "pay for performance" in 5 districts. Legislature approved governor's proposal for state share of 9.7% and 10% salary increases in 1985 and 1986.
Washington	$13 000/9 months	UC	UC	Y	Y	UC	1984 legislature did not take up many educational-reform measures; 1985 is expected to be better for educational reform.
West Virginia	$14 500 to $15 000 per 10 months	Y	UC	N	UC	Y	Legislature raised average salary by $2000 (1984). State board of education edict that all high-school students must have opportunity to take physics, trigonometry and foreign language (1984).
Wisconsin	Varies	UC	UC	Y	UC	UC	Property-tax relief and overall level of funding for education will be major items before legislature.
Wyoming	$18 000 to $20 000 per 10 months	N	N	N	Y	N	Approved $2500 for scholarships for math and science teachers to upgrade skills at University of Wyoming during summers (1983).
District of Columbia	$17 167/10 months	NA	N	Y	NA	NA	
American Samoa	$9300/10 months	Y	UC	N	NA	NA	"Off-island" contracts include transportation, shipping allowance, 100% medical–dental, $75/month housing and round-trip air fare every two years. New graduation requirements include 3 years each of science and math.

NA, Not available UC, Under consideration
* Recent salary increases or new minimum salary
† Career-ladder or merit-pay program instituted
‡ Collective-bargaining or binding-arbitration agreements in place
§ Financial aid for prospective teachers available
** Revised requirements for certification

Physics teachers at summer workshops. Many teachers find such workshops stimulating and instructive—an occasion to "recharge their batteries." (Photographs courtesy of AAPT.)

of *Education Week*, and covered the period up to January 1985. In an effort to update that report with more-recent state initiatives and to obtain more-specific information regarding physics education, I sent a follow-up survey to members of the Council of State Science Supervisors in June 1985.

Some of the results obtained by *Education Week* and by our survey are tabulated state by state in the accompanying chart and maps. Information provided by the science supervisors of the District of Columbia and American Samoa is also included in the chart. The responses we received from the state science supervisors regarding the percentages of graduating high-school seniors in their states who have taken a class in physics and whether or not their states have shortages of qualified physics or mathematics teachers are presented in the map on page 44.

One of the difficulties with the survey was that in 27 states the number of graduating seniors who have taken physics was either unavailable or available only as an estimate from the state science supervisor. Among the states for which information was available, the variation from state to state is rather surprising—ranging from, at the low end, Oregon (3.5%), Kentucky (approximately 4%) and South Carolina (4%) to, at the upper end, New York (28%), Michigan (about 30%) and Pennsylvania (30%).

The responses confirm that the shortage of qualified physics and mathematics teachers is still a critical problem. Only North Dakota, Rhode Island and Wyoming report an adequate supply of qualified physics and mathematics teachers. Montana and Kansas report an adequate supply of mathematics teachers, but a shortage of physics teachers. In the remaining states there is still an inadequate supply in both fields.

The responses to the question regarding the current minimum starting salary (see second column of chart) frequently indicated that this figure is set by the local district and that the legislated state minimum salary does not accurately represent the starting salaries in most districts. It is interesting, however, to note the values reported in a few states: Alabama ($20 000/10 months), Wyoming ($18–20 000/10 months), Georgia (more than $18 000/10 months) and California ($18 000/10 months). For minima, these values are quite high: The current estimated[7] average salary for all teachers nationwide is only $23 546.

Career incentives

The most frustrating finding is the small number of states that have actually increased salaries. Only 17 states have taken this vital step during the past two years and in 18 additional states the matter was reported still to be under consideration as of June 1985. The urgency of improving teacher salaries is expressed[8] well in a report of the State Board of Education in Connecticut:

Salaries for teachers historically

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have been lower than for professionals of comparable training in other fields.... Teachers' starting and continuing salaries must be made competitive with those earned by persons with comparable skills and training in the private sector.

It is doubtful that a real solution to the shortage of science teachers will ever be achieved without more progress in this critical area. A great push on the part of those concerned with quality science and mathematics education is still urgently needed in this area.

Many have suggested that one tangible method for recognizing effective teachers might be the implementation of merit-pay or career-ladder systems. Twelve states have already approved programs of this type and 26 more have them under consideration.

It has been suggested that collective-bargaining agreements might provide a barrier to the implementation of merit-pay or career-ladder programs. The responses to our survey indicate that 10 of the 30 states (not counting the District of Columbia) in which a collective-bargaining or binding-arbitration agreement exists on a statewide basis (or in most of the local districts) have already approved some type of merit-pay or career-ladder program and that they are under consideration in 14 other states.

A common response to the crisis has been the creation by the states of financial-aid programs for prospective teachers, particularly for those in fields with critical shortages. We found that 27 states have already approved such programs and that 11 are considering them. In most cases these involve "forgivable loan" programs in which the student receiving aid is committed to a certain number of years of teaching in the shortage field for each year of assistance received. If the student leaves teaching prior to the end of the commitment, the aid converts from a grant to a loan that must be repaid to the state.

Some 29 states have revised their certification requirements, and 16 more states are considering such changes. Of particular interest are the so-called alternative certification programs[9] that have been adopted in California, Florida, New Jersey and Texas. These programs allow individuals with degrees in areas in which they desire to teach to become teachers without taking the usual college education courses. In the Texas program, with which I am most familiar, a teacher is hired at the normal starting salary by a district that has been approved for this program, and is given a normal teaching assignment. But during the first year, he is identified as an intern and supervised by a master teacher. The hiring district assumes responsibility for providing during the first year the pedagogical training that might be required. If the teacher's performance is adequate, full certification is granted at the end of that year.

An article by Dianna Hunt of the *Houston Chronicle* reported[10] that by July more than 1500 calls from across the nation had been received by the Houston Independent School District as word about the Texas program spread. In New Jersey the alternative program had already attracted 965 candidates by early June.[11] The candidates for the New Jersey program are mostly nonteachers looking to change careers, but also include 50 graduating seniors recruited by the state from "some of the nation's most prestigious colleges and universities... including Harvard, Brown, Princeton, Yale, Mount Holyoke, Smith and Swarthmore."[11]

The responses to the programs in New Jersey and Texas indicate that programs of this type can be very valuable in attracting to precollege physics and mathematics teaching individuals with strong backgrounds in the subjects but without prior certification. Hunt also mentioned that the beginning salary for those entering teaching through the program in Houston was expected to be $20 000 for ten months, with bonuses of as much as $3000 given for each four to five years of experience in business or industry.

Increased requirements

Most states have increased their mathematics and science requirements for high-school graduation (see figure, page 45). The responses to our survey indicate that 45 states have legislated changes and an additional three are considering reforms in this area. Unfortunately, when we look closely at the specific changes we find that with the exception of a few notable cases, such as Florida, Louisiana, South Dakota and Vermont, the new graduation standards require only two years of mathematics and two years of science. This may have only a minimal effect on physics enrollment because physics is usually taken in the senior year and is normally the third or fourth science course to be taken by the student.

A number of states report an increase in the requirements for college admission. Eighteen states have increased college-admission requirements, with two additional states still considering this change. Because admission standards are usually set by colleges and universities themselves, these figures are probably not too significant.

Many proposals for educational reform are dependent on increased funding for education. In this area the news is positive. The *Education Week* survey reports[8] that "all of the 50 states have increased their education budgets in the past two years and virtually every governor has proposed a substantial, and in some cases dramatic, increase in education for 1985–86." The report attributes this in part to the fact that 37 states ended 1984 with budget surpluses while only three states experienced deficits. This favorable financial condition affects both teacher compensation and the availability of funds for instructional material and teaching apparatus. A number of states have already increased their budgets for instructional equipment in science. The most notable are the programs in California, Florida, Tennessee and Virginia.

In summary, the past two years have been years of unprecedented progress, but the battle is far from won. The media are now turning their attention to other problems. There is a great need for the scientific community to keep up the pressure for improvements while governments and the public still show some interest in education. It may be many years before such an opportunity to improve physics and mathematics education at the precollege level returns.

* * *

I should like to express my heartfelt appreciation to the Council of State Science Supervisors and its members for their assistance with and response to our survey, to Margaret O'Brien for her efforts in the survey mailing and follow-up and to Sharon Jensen and Lucy Cheung for their contributions in the preparation of the text and the table.

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