Overview of the problem

Our present situation is the culmination of a long trend—interrupted only weakly in the Sputnik era—of declining enrollments in physics, but the state of the economy may provide a new context.

John W. Layman

Science and mathematics education in this country is in a precarious state. Most of our students do not learn nearly as much as they could and many of our teachers are ill prepared. That the state of affairs has deteriorated to the point of becoming a crisis is confirmed by the number of editorials in our journals, the amount of legislation being proposed at all levels, the attention given the subject in the popular press and the number of meetings held to discuss the crisis. Thus, for example, the National Academy of Sciences sponsored a national convocation (May 1982) to consider the state of precollege education in the United States. The topic also received special attention in October 1982 at The American Institute of Physics Corporate Associates meeting and at the Spring 1983 meeting of the AIP Assembly of Society Officers and the AIP Governing Board meeting.

For the younger members of the physics community the crisis appears as a new problem and challenge. For the older members it may serve as a reminder of longstanding tasks and challenges yet to be solved.

We are facing some critical problems in this country in our ability to offer the science and mathematics courses that all students need—the average students as well as those students who wish to pursue science or mathematics as a career or career base. In the past we have done well for our best students. Those coming to the universities to study physical sciences have had the highest test scores, and until recently these scores had not fallen as had the test scores of the general student population. In fact, the scores of students taking the Physics examination in the Admissions Testing Program increased[1] significantly from 1979 to 1981.

However, in an article highlighting some recent findings of the science portion of the National Assessment of Educational Progress we find[2] the following statement:

> American students with poor academic track records made major gains in reading during the 1970s, with blacks making the most progress, but academically able teenagers lost ground particularly in math and science.
>
> Declines in science were greatest among the highest achievers, especially white high achievers at ages 9 and 13.

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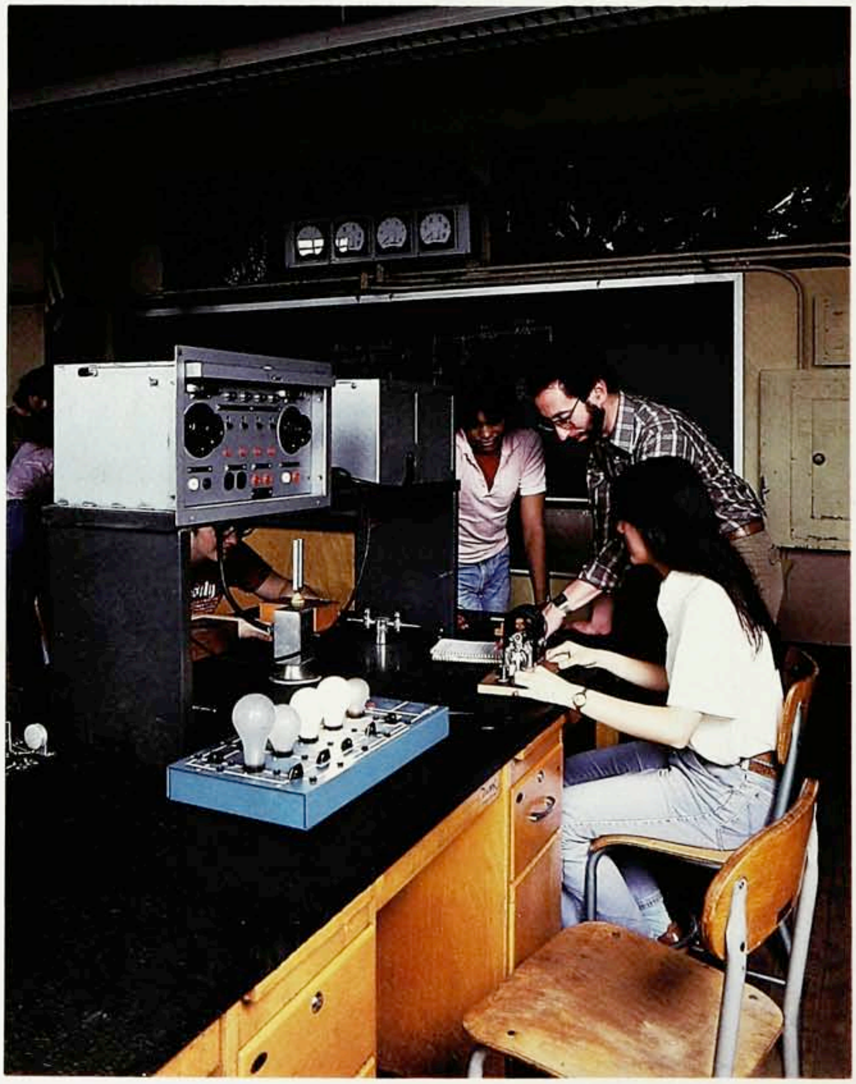

Despite an optimistic feeling from early reports in 1982 that the scores on the Scholastic Achievement Test may have risen slightly, the present report of the Education Commission of the States seems to counteract that. We may be losing ground with some of our very best students, the source of many of our science majors, and certainly the source of the scientifically trained manpower of vital concern to our country.

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One hopes, of course, that our high-school physics enrollments are not taken from just the group of the most talented students. Estimates of actual enrollments in high-school physics are hard to come by. In 1977 an NSF study found that physics courses account for 3.1% of total secondary science enrollments. In 1982, 20 percent of the graduating high-school seniors had taken physics at some point—a figure obtained from an analysis[4] of the National Center for Educational Statistics tapes of data from their study *High School and Beyond*; the analysis was performed by the AIP Manpower Statistics division. (These two enrollment figures refer to different types of data and therefore do not indicate an improvement between 1977 and 1982.)

In too many schools physics is an elective—in many cases taken chiefly by 12th grade, college-bound students planning to major in the physical sciences. The NSF report *Science and Engineering Education for the 1980s and Beyond* included a discussion of students' participation in the various sciences. It contained[3] the following strongly worded statement:

> After grade 10, the situation changed dramatically. Enrollment in chemistry and physics, the two engineering preparatory courses, accounted for only 6.9 percent and 3.1 percent, respectively, of total secondary science enrollments.

There is no evidence of a major improvement in physics enrollments among the general student population since 1977, so our major success seems to be only among the college-bound students—if 20% is a satisfactory level. It appears that the physics community cannot claim to be attracting or serving the broader set of students who could benefit from the study of our discipline.

Of course, as I indicated earlier, in the US physics is an elective, confined for the most part to one year of study, usually the senior year. In countries such as Japan, Germany, and the USSR, physics is required of all students and often begins in the lower grades. The Japanese education system, with its greater emphasis on science and mathematics, is often cited as one factor in their emergence as a technologically powerful nation.

Teachers

There are now virtually no science teachers in the pipeline. This is especially true in physics and mathematics. There are 65% fewer science teachers in training now than 10 years ago. This change occurred[5] during a period when the student population dropped by only 12–13%. When vacancies occur in a science or math position, the present solution in many districts is to shift an underprepared teacher into that slot rather than dismiss teachers. Many of the vacancies in physics and mathematics occur in districts that are closing schools and dismissing teachers—regardless of their having tenure—due to diminishing student numbers. Some of the most recently hired and first fired are science teachers with specialized skills; the job insecurity certainly discourages other new teachers from entering the field—no matter what publicity there may be about science-teacher shortages.

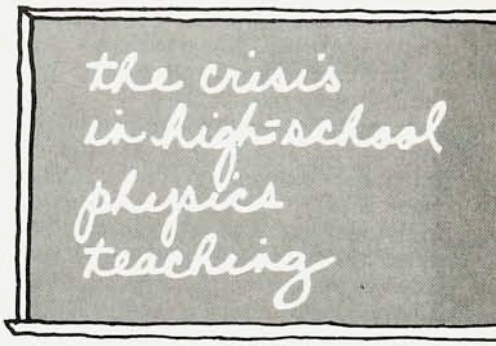
The qualifications of those now teaching is also a great problem. In Iowa, for instance, 63% of those teaching physics do not have a major or even a minor in physics. A national survey, also conducted by the group in Iowa, found that half of the newly employed science and mathematics teachers were not qualified to teach science or mathematics; they were employed on an "emergency" basis because no qualified teachers could be found. The figure ranges[5] from 75% in the Pacific states, to 9% in the northeastern states, with a national average of 50%.

A survey by the National Science Teachers Association shows[5] further that schools have an aging faculty and that one in four of the younger faculty plans to leave teaching completely. The average age of science teachers is 41 and they have an average of 16 years of experience.

We thus have a multitude of problems: low enrollments in physics, "highest achievement" students whose test scores have fallen, few teachers in training, many of those now teaching physics poorly qualified for this task, and many of our best qualified teachers either leaving teaching completely or approaching retirement age.

The special role of physics

Today when we speak of the teacher shortage at the secondary level as a "crisis in science education," we are not referring to equal shortages in all science areas, but to a crisis that is most severe in physics. The 1983 survey[6] of teacher placement offices by the Association for School, College, and University Staffing lists physics in the "considerable teacher shortage" category, with a score of 4.46 on a 5-point scale (5 = greatest demand, 1 = least demand). Mathematics and chemistry fall into the same category, mathematics with a score of 4.75, and chemistry with a score of 4.30. Biology falls into the category of "slight teacher shortage" with a score of 4.10. For the first time physics stands out as having the most severe shortage of qualified teachers among the sciences. It is our community that is being highlighted as needing to provide potential solutions for the present crisis.



I do not want to imply that there are not crises at other levels. Physical science plays a role in elementary and middle-school science, and there is a shortage of well-prepared teachers at those levels as well. We shall, however, concentrate on the secondary level.

Antecedents to today's crisis

Are these concerns with students and teachers new concerns within the physics community? Decidedly not. Consider, for example, the following comment:[7]

> The enrollment in physics in public high schools of the United States has decreased steadily during the past six decades. In 1895, about 23% of all high-school pupils were enrolled in physics. Over 95% of those graduating in that year had taken a course in physics. In 1952, about 4.3% of high-school pupils were enrolled in physics and approximately 21% of the graduates of that year had studied physics. Thus, high-school physics has declined in the same period that saw physics rise to new importance in our national life.

Or the following:[8]

> A severe educational crisis for physics appears to be in the making in our high schools, where the fraction of students having a course in physics—never very large in the past—has been seriously declining. A major cause for the decline . . . is the shortage, or even absence, of competent physics teachers in many secondary-school systems.

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Students. The first statement was made in 1955 by William C. Kelly in an article in PHYSICS TODAY. The graphs on this page and the next are adapted from that article; later enrollment figures have been added to Kelly's data.

Enrollment data[9] from 1961 to 1973 show an increase in the overall secondary-school student population of 59% but an increase of only 45% in the number of students enrolled in physics, so during that period physics was still falling behind. The enrollment figures from 1977 and 1982 that I mentioned earlier to support the existence of a present crisis, literally match Kelly's 1955 data. Things have not changed much in the intervening period.

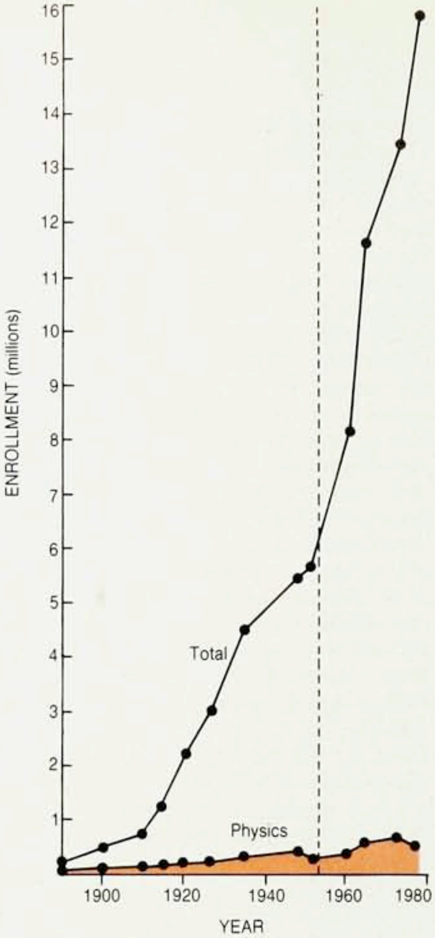
In his 1955 article, Kelly suggested that the direction and inspiration to improve physics courses, to make them more attractive for more students, had to come from national organizations as well as from the work of many physicists and friends of physics. He suggested that improvements needed to be made in the content of courses, in the adequacy of equipment, in insuring adequate time for laboratory work and classroom demonstrations, in offering differential treatment according to student abilities, and in providing the "public relations" that physics needed. He was bold enough to suggest that the future of high-school physics would be decided within the next decade (1955–1965).

Teachers. An article in PHYSICS TODAY in 1956 that provided a listing of summer institutes for high-school science teachers contained[10] the following statement:

> The shortage of scientifically trained personnel has been clearly established. The most ominous aspect of this is the "drying up of the fountainhead" through the relative and even absolute decline in college science student enrollments. Perhaps the greatest single factor in stimulating students into seeking science careers is the enthusiastic and well-informed high-school science teacher.

A little more than a year later, in October 1957, the Russians launched Sputnik I. The resulting public alarm over the perceived sorry state of US science education allowed an increase in budget appropriations for teacher preparation and curriculum development, programs that had already been proposed by the scientific community and were in the planning stage at NSF prior to the launching of Sputnik I.

In 1959 the Cooperative Committee on the Teaching of Science and Mathematics of the American Association for the Advancement of Science expressed concern with teacher preparation. The report went on to describe undergraduate physics programs suitable for teacher preparation and encouraged all concerned to attract more persons into science teaching. William Buchta, in decrying the status of science in the high schools, indicated[11] that the "entire educational hierarchy, including college and university science staffs, and the public generally, must share the onus."



Enrollment in public high schools in the US. The curves show total number of students (upper curve) and students enrolled in physics courses. Data up to 1952 are from William Kelly's 1955 article[7] on physics in the public high schools; data from subsequent years come from the Department of Education and the National Center for Educational Statistics. (Compulsory-attendance laws went into effect in most states before 1910, and in many before 1890; they thus account for only a small part of the changes shown here.)

In August of 1964 AIP established a Precollege Physics Office and along with the American Association of Physics Teachers commissioned[12] Victor Young to "investigate reasons for low enrollment in high-school physics." Young carried out this investigation through personal visits to a variety of schools and produced a set of recommendations rather than a description of physics teaching at that time.

Young's recommendations, made in 1965—the end of Kelly's decade—included establishing a regular and well-informed lobby to work with legislators at all levels, providing endorsements for qualified physics teachers, establishing ways to encourage research into physics teaching, and finally encouraging professors to look upon each student beginning an undergraduate physics program as a potential high-school physics teacher.

The second of the two statements I used to illustrate antecedents of the present crisis was made in 1965 by a physics survey Committee of NAS in the course of commenting on the failure of the physics profession to communicate with the general public and pointing out further difficulties due to potential teacher shortages "in the future."

In May of 1966 the Commission on College Physics established a Panel on the Preparation of Physics Teachers, which in turn sponsored[14] a workshop to "develop a plan of action which would encourage college and university departments of physics to accept increased responsibility for establishing realistic academic programs for prospective high-school teachers and for the recruiting of students into these programs." In the Introduction to its report, the panel said[4]

> We believe that the shortage of qualified high-school physics teachers is one of the most pressing problems facing American physics today in that its solution is central to the future vitality of our profession.

The Report goes on to document the shortage; it discusses building teacher-preparation programs, describes some of the existing programs and finally discusses recruiting teachers.

The Report was quite critical of academic physics departments in contrast to those in teachers colleges. The 1966 survey had revealed[14] that:

> 1. Well-known, high-prestige departments rarely have programs specifically tailored to the needs of the prospective high-school physics teacher. They recommend the regular physics-major program.
> 2. These same departments typically graduate two or three teachers every five years, and
> 3. Less than ten of the schools surveyed graduate more than five physics teachers per year (having at least 18 semester-hours in physics).

Today many of these physics departments formerly found in teachers colleges have been transformed into regular departments in institutions that are no longer identified as "teachers colleges." Our problems today are even more severe than in 1960.

The most comprehensive review and evaluation of the physics and physics-education community was presented in the 1972 NAS study, *Physics in Perspective*. This report emphasized great concern for teaching science and physics to the general public—beginning in the early school years. This report again stressed the crucial role that well-prepared science teachers can play, and it emphasized the obligation of physics departments in universities and colleges to offer the pre-service and in-service courses that such teachers need. The report clearly identified the colleges and universities as "custodians of physics, and they teach—or do not teach—those that emerge from their halls to teach the young."

Suggestions for dealing with the shortage and preparation of physics teachers came from many other sources and included improving high-school teaching conditions by, for example, raising salaries, providing summer support activities, spending more for equipment, providing some paraprofessional help and providing extra pay for extra work.

In the post-Sputnik era NSF responded with generous support for curriculum-development projects, the first of which was the Physical Science Study Committee course. Physics set the tone and led the science community in this effort. NSF also provided monies both for programs to prepare teachers to use these new curriculums as well as for general training or retraining or work toward an advanced degree. Among science teachers, physics teachers had the highest percentage of attendance at NSF institutes and programs. This means that many physics departments designed and sponsored programs for physics teachers. Private organizations did the same. General Electric Fellowships and Shell Merit Fellowships were two examples.

How valuable were all of these suggestions and recommendations? Could anyone have taken them seriously, if, as it is said, the crisis still persists—and is there any reason to assume that there will be any more success in dealing with these same problems in the future?

The crisis: a new context?

The US finds itself challenged in many sectors of the economy, particularly in the industrial and high-technology marketplace. Science, or at least the contribution science can make in building a technologically literate workforce, is no longer just of concern in the isolated laboratory and research university. This situation led Frank Press, the president of NAS, to speak[16] of "raising a generation of Americans who lack the education to participate in a technological age," and suggested to the American scientific and teaching community that we reaffirm the commitment that Jerrold R. Zacharias asked of us 20 years ago: "A permanent sustained commitment of the American scientific community to enlarge its presence in the American classroom."

The loss of American dominance in world markets is often tied directly to our education system and to the failing role played in that system by science and mathematics. Science and engineering have been described as the "liberal arts" of Japan, where 65% of the baccalaureate degrees are awarded in scientific fields in comparison with 30% in the US. Issak Wirszup of the University of Chicago has described some of the differences in commitment to science and mathematics in the USSR and in our own country. When a student has finished the mandatory 10 years of schooling in the USSR, that student will have studied five years of physics and algebra, ten years of geometry, two years of calculus, four years of chemistry, one year of astronomy, and five and one half years of biology (PHYSICS TODAY, December 1980, page 53). This stands in great contrast to the small percentage of US students that take any math or science beyond the

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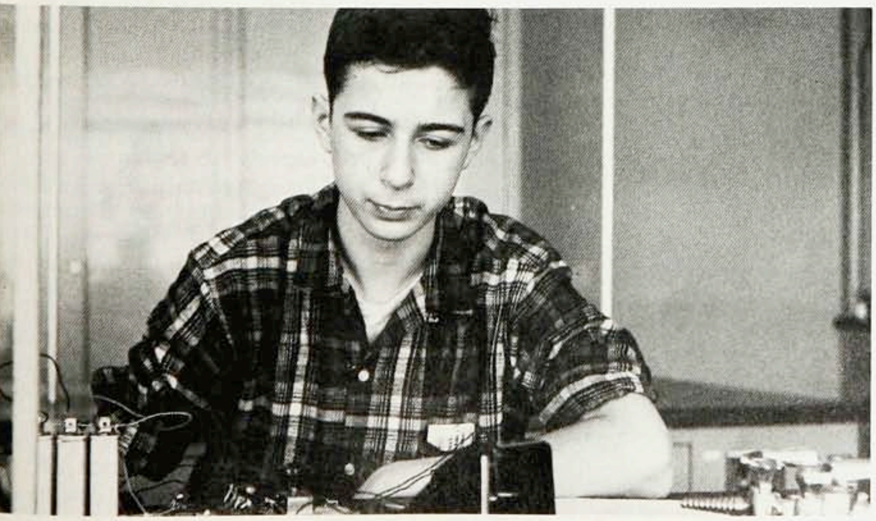

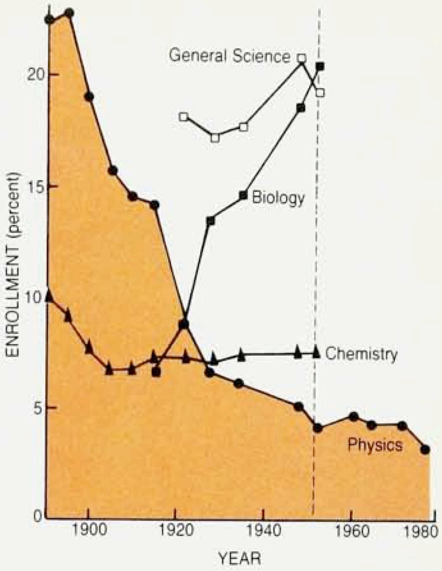

Fraction of students enrolled in physics and various other science courses. The curves up to 1952 come from Kelly's 1955 article in PHYSICS TODAY, subsequent data are from NCES and the Department of Education.

10th grade, much less a course in physics or calculus.

Sheldon Glashow (PHYSICS TODAY, April, page 9), in voicing concern at the loss of US preeminence in science, points to the greater per capita European investment in science education and research in the latter part of the 20th century and to the almost total lack in the US of precollege teachers with competence in science and mathematics. His general conclusion is that our reduced research expenditures and lack of qualified teachers may force us to pass the torch of scientific endeavor to other peoples.

Is this nation's position within the world community in enough jeopardy to provide a "new context" to bring about the "permanent and sustained commitment of the American scientific community to a presence in the American classroom"? There is a rising tide of indignation about the "rising tide of mediocrity" in this country. Physics has always been perceived as standing aloof from mediocrity—requiring serious efforts, great intelligence and advanced mathematics to be studied properly. Judging from the comments and recommendations of our own colleagues who have studied our efforts over the past 25 years or so, we must strive to lower our exclusivity so that at least some of the students stepping out of the tide of mediocrity will feel welcome in the role that physics could play in their lives. We must be sure that there will be qualified teachers to introduce them to this role.

Other articles in this issue of PHYSICS TODAY will describe present conditions more fully, pointing out why physics graduates don't become teachers (page

32), suggesting paths to a solution (page 44), even describing, fortunately, examples of where things are going right (page 52).

References

1. *Science and Engineering Education: Data and Information*, National Science Foundation (1981), page 128.
2. R. Brown, *National Assessment Findings and Educational Policy Questions*, SY-CA-50, Education Commission of the States (1982).
3. *Science and Engineering Education for the 1980s and Beyond*, NSF 80-78, National Science Foundation (1980), page 47.
4. AIP Manpower Statistics Division, Results of the AIP analysis of the NCES tapes from *High School and Beyond*, preliminary report (unpublished).
5. S. E. Klein, NSTA Testimony to the Labor and Human Resources Committee of the US Senate, 15 April 1982.
6. J. N. Akin, *Teachers Supply/Demand 1983*, Association for School, College and University Staffing (1983).
7. W. C. Kelly, PHYSICS TODAY, March 1955, page 12.
8. *Physics: Survey and Outlook*, National Academy of Sciences (1966), page 30.
9. *The State of School Science*, National Research Council (1979), page 20.
10. R. L. Weber, PHYSICS TODAY, March 1956, page 30.
11. J. W. Buchta, PHYSICS TODAY, September 1959, page 35.
12. V. J. Young, *A Third Report on a Pre-College Physics Study*, AIP Department of Education and Manpower (1965), page 3.
13. V. J. Young, Phys. Teach., January 1966, page 20.
14. *Preparing High School Physics Teachers*, Commission of College Physics (1968), page 1 (this report is available from AAPT).
15. *Physics in Perspective*, National Academy of Sciences (1972), page 756.
16. F. Press, Science **216**, 1055 (1982). □