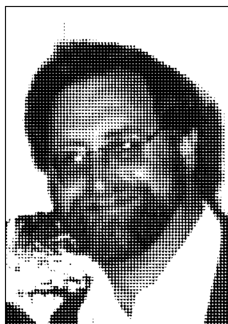
Background and Professional Qualifications of High-School Physics Teachers

Michael Neuschatz and **Mark McFarling**



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It is not unusual to hear journalists, and even on occasion renowned physicists, decry the lack of qualified high-school physics teachers in the United States. They often buttress their view with an anecdote about a football coach or home economics teacher stumbling through Newton's laws, or a restatement of the "well-known fact" that a substantial fraction (often given as half) of all high-school physics teachers never even took physics in college.

The more such "facts" and stories are repeated, the more authoritative they sound. However, there is a good deal of evidence to suggest that they are simply not accurate depictions of reality. One source of better-than-anecdotal data to evaluate these beliefs is the "Nationwide Survey of High School Physics Teachers,"[1] conducted by the American Institute of Physics in 1997 and three times prior to that over the past dozen years. The findings from that study indicate that high-school physics teachers tend to be better trained than they are often given credit for, and that instances of utterly unqualified instructors are rare. This in no way implies that there is a generous supply of well-trained high-school physics teachers ready to lead classes in the subject. But the study does show that the situation is less dire than is often depicted and that, if anything, teacher preparation seems to be improving, albeit slowly.

The AIP database comprises information supplied by principals and physics teachers in a representative sample of over 3,000 public and private high schools across the country. Participation rates by principals have always exceeded 99%, and response rates from teachers have consistently been around 75% for the four rounds of this longitudinal survey. The teacher questionnaire focuses on a wide variety of issues, including: teacher demographics and background; the character of the school and its physics program; the teachers' current work circumstances and their assessment of the challenges they face; and their career satisfaction and plans for the future.

Academic Background

In terms of broad academic credentials, teachers with graduate degrees are well represented among physics instructors, with 58% holding a master's degree and 4% with a Ph.D. Among teachers with more than five years experience, the fraction with a graduate degree rises to 67%. However, the real concern has always revolved about the teachers' specific preparation in physics. As Fig. 1 demonstrates, a smaller but still notable frac-

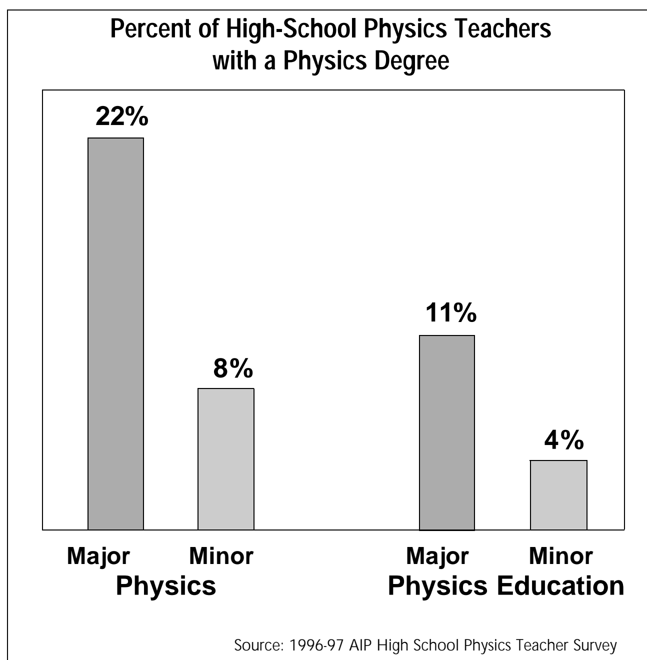


Fig. 1.

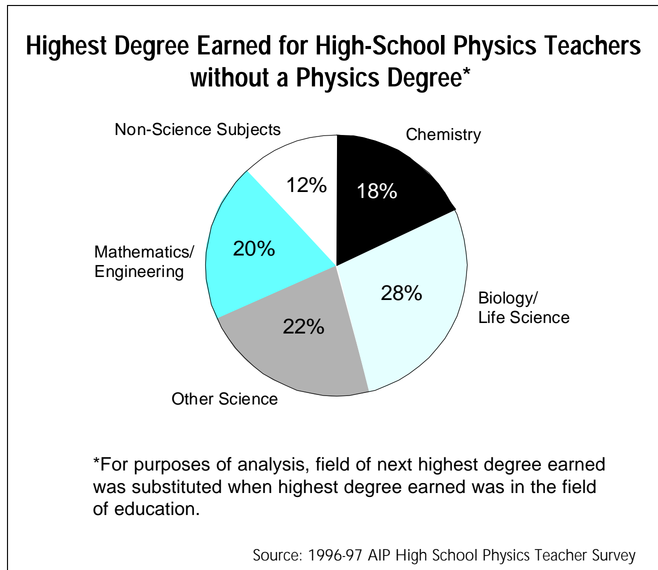


Fig. 2.

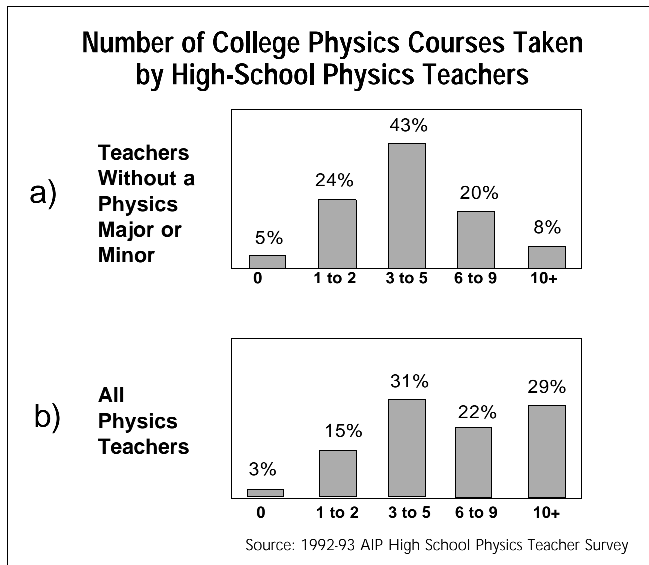
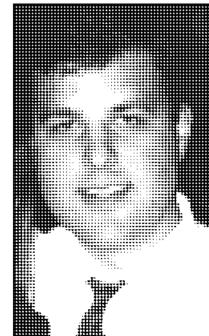


Fig. 3.

tion of the teachers report having earned a college degree specifically in physics. Slightly more than a fifth of the teachers with physics classes in 1997 earned an undergraduate or graduate degree in physics, and when we include those with a degree specifically in physics education, the fraction rises to one-third. Adding in those who said they had a formal minor in either physics or physics education brings the total to 45%.

Nevertheless, these results only partly address the fears that have been raised regarding physics-teacher preparation. At least as great a concern has been voiced regarding the background of the *other half* of physics teachers, those who did not major or minor in the field. However, here too, we found that the situation does not appear to be as dismal as is sometimes suggested. For one thing, as shown in Fig. 2, the overwhelming majority concentrated their studies either in mathematics or in one of the other natural sciences. This is hardly surprising, given that most of these teachers have math or another science as their primary teaching specialty, and teach physics as a secondary subject. Nevertheless, to satisfy the requirements for their nonphysics degree, these



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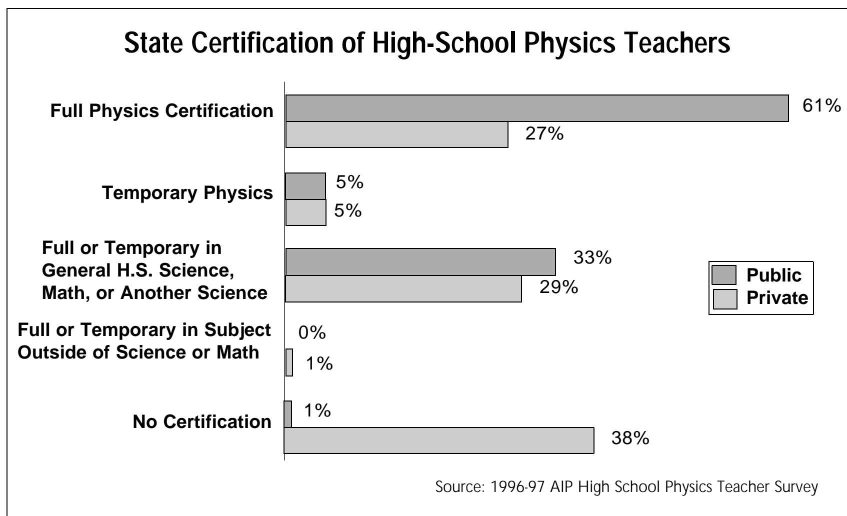

Fig. 4.

Table I. Distribution of types of physics teachers by type of school.

	Percent of school's physics teachers who are:		
	Specialists	Career Teachers	Occasional Teachers
School size (Number of seniors public only)			
1-50	15	45	40
51-199	26	48	26
200+	41	37	22
School setting			
Central city of large metro. area	40	36	24
Suburbs of large metro. area	44	32	24
Smaller metropolitan area	36	41	24
Small city/large town	33	43	24
Rural or small town	22	48	30
Type of school			
Public	33	39	28
Private	31	42	27
Geographic location			
South	24	43	33
Rest of country	34	41	25
Number of physics teachers at school			
1	26	45	29
2	42	35	23
3 or more	49	30	21
Socioecomonic profile of school (public only)			
Much better off than average for area	48	32	20
Somewhat better off than average	38	39	23
About average	29	44	27
Somewhat worse off than average	26	47	27
Much worse off than average	19	44	37
Racial composition of school			
Half or fewer minority students	34	43	23
More than half minority students	28	42	30
Number of Respondents	641	835	544

teachers typically had to take at least one and often several courses in college physics. Evidence of this emerged from data collected in the 1993 survey, when teachers were asked specifically about the number of undergraduate and graduate physics courses they had taken in college. As Fig. 3a shows, 95% reported taking at least one college physics course, and 71% took three or more such courses. Among all physics teachers, only 3% had no college physics and 82% had taken at least three college physics courses (see Fig. 3b).

Classroom Experience

While the findings on academic background provide some reassurance that the majority of high-school physics teachers have at least some formal classroom training in the discipline, information on official teacher certification sheds little additional light on the situation. On the surface, the evidence is heartening: the majority of public-school teachers report having full teaching licenses specifically in physics (see Fig. 4), and virtually all of the rest are fully certified to teach science or math. While private-school teachers are often not governed by official certification rules, many of them also boast teaching licenses in physics or a related field. Unfortunately, the requirements for certification are often very broad, and even among public schools rest on varying definitions and criteria and often differ greatly from state to state. This makes official certification a less effective yardstick than prior specific academic coursework for gauging and comparing teacher qualifications nationally.

Moreover, it is widely accepted that effective teaching requires not only formal academic training, but also consistent practice to hone techniques for maintaining effective communication with students. While college coursework and official certification may provide some basis for encouragement, the same cannot be said for the opportunity most high-school physics teachers have to concentrate on the subject and develop their skills in the trenches. During the 1996-97 academic year, for example, we found that only about a fifth of all responding teachers taught physics classes exclusively. In fact, only about a third taught even a majority of their classes in physics. And when we focused on past experience, we found that for around 60% of teachers, there had been at least one year, and often many more, when they were not assigned even a single physics class to teach.

Career Specialization

We decided to create a specialization measure to embody the two related components of formal academic training and consistency of teaching experience. When we examined the data more closely, it seemed that teachers clustered into three distinct groups, of roughly equal size. First, there were those who had earned a degree in physics or physics education. Not surprisingly, almost all of these teachers were consistently assigned to teach physics throughout their careers. We labeled these teachers physics "specialists." Then came those teachers who did not have a degree specifically in physics, but nevertheless had taught it repeatedly, often as much as they taught the subject in which they had earned a formal degree. These teachers were labeled "career" physics teachers. We found, and noted in an earlier report,[2] that these teachers generally expressed greater self-confidence about their physics knowledge and teaching skills as they

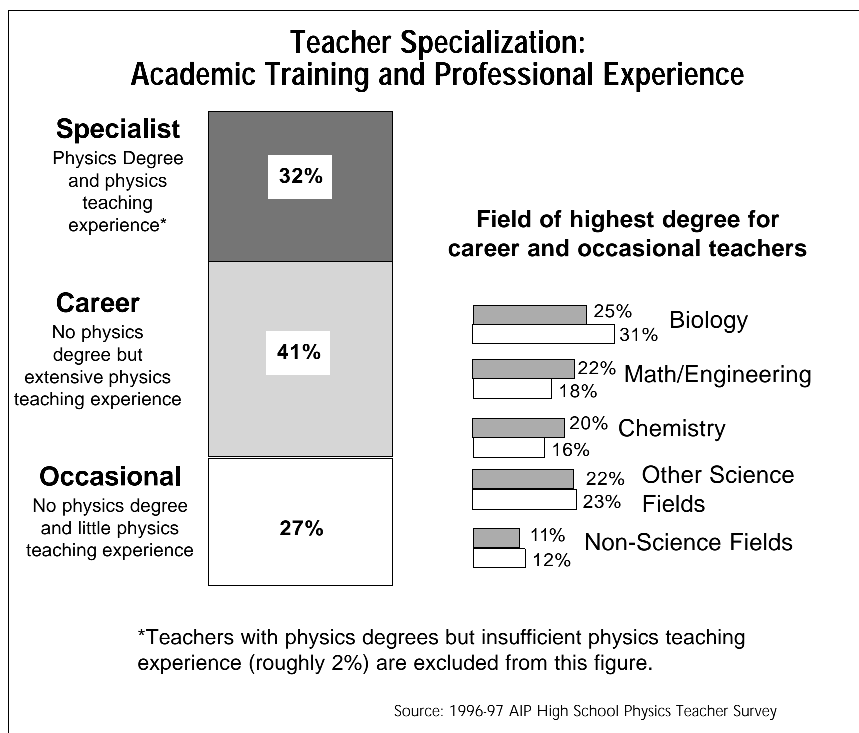

Fig. 5.

acquired more physics-teaching experience. Finally, there was a third group, labeled "occasional" teachers, who happened to be teaching physics at the time of the survey, but who had neither earned a degree in the field nor had taught physics consistently during their career. It was here that the problems of poor physics preparation and inadequate administrative support emerged most strongly. Teachers in this group often experience a pattern of irregular and unpredictable movement in and out of physics teaching from year to year, depending on enrollments and the availability of more highly trained staff. At small schools, the situation may be further complicated by the fact that physics courses may be offered only in alternate years. The result of the specialization measure, depicted in Fig. 5, illustrates the overall percentage of teachers in each category and the disciplines from which those without formal physics degrees are recruited.

While these three specialization categories contain roughly equal numbers of physics teachers overall, closer examination (see Table I) shows that they are not evenly distributed across schools and physics programs around the country. For one thing, larger schools, with their higher potential physics enrollments, are far more likely to have physics teachers who are specialists in the field than are smaller schools. However, among private schools, smaller size is offset by their college-preparatory orientation and the generally high percentage of their students who take physics, so private schools field physics specialists as often as the generally much larger public schools do. The impact of school size probably accounts for the greater prevalence of specialists in schools in larger metropolitan areas as against rural schools. Along similar lines, teachers at schools with physics enrollments large enough to support more than one physics instructor are far more likely to be specialists than those who are the only physics teacher at their school.

Other sharp contrasts emerge along the lines of social class. Schools whose students are judged by teachers to be economically better off than the average for their area are far more likely to have specialist physics teachers than schools whose students are judged worse off than average. Interestingly, the disparity in the presence of specialists between minority majority and white majority schools seems largely a product of this social class difference, although the disparity may often be experienced and expressed primarily in racial terms. Thus, it is the fact that minorities are overrepresented among the lower economic levels that, for the most part, gives rise to the very real scarcity of specialists in their physics classes.

The impact of school environment on physics-teacher background carries over into what is probably a reciprocal and mutually reinforcing relationship between teacher background and the condition of the physics program, as shown in Table II. Better-trained teachers attract more students to physics, and this in turn makes it possible for those teachers to use their training in more creative and effective ways. For example, such teachers may be able to provide a

Table II. Distribution of types of physics teachers by characteristics of physics program.

	Percent of school's physics teachers who are:		
	Specialists	Career Teachers	Occasional Teachers
% of students taking physics prior to graduation			
Fewer than one in six	21	47	32
One-sixth to one-third	27	43	30
More than one-third	40	38	22
Funds available per class (1997$)			
0 to 150	30	41	29
151 to 300	34	42	24
301 to 500	34	44	22
501+	33	42	25
School Offers AP/2nd year physics			
AP offered	47	34	19
AP not offered	25	45	30

Table III. Teacher characteristics by specialization category.

	Specialists	Career Teachers	Occasional Teachers
% reporting poor preparation in the following aspects of physics teaching:			
Use of computers in physics instruction and labs	29	49	56
Recent developments in physics	17	36	50
Instructional laboratory design and demonstration	8	12	26
Other science knowledge	5	3	4
Application of physics to everyday experiences	4	7	13
Basic physic knowledge	0	2	5
% who are AAPT members	40	24	14
% who are NSTA members	33	42	34
Professional development activities			
% who attended a physics education workshop	42	36	31
% who attended physics association local or national meeting	25	18	9
% who changed topics in basic introductory physics course	36	32	24

more diverse curriculum, including advanced courses as well as courses with innovative designs to attract and hold the interest of students with poor math skills. Even though actual monetary resources provided seem to be no different, specialist teachers may be able to translate the available resources into more engaging learning experiences, helping to increase still further the percentage of students taking physics before they graduate.

Table III illustrates some of the ways in which background has an impact on teachers' sense of mastery over their material, as well as on their involvement in professional organizations and in activities designed to hone their professional skills. Differences between physics specialists and the other two groups, especially in their familiarity with recent developments in the field and their ability to incorporate computers in their physics classrooms and labs, probably originate from differences in initial training, specifically in physics and physics teaching. However, it is also worth noting that career teachers show significantly more self-confidence in recent physics developments, and also in general laboratory instructional skills, than the occasional physics teachers. The fact that the only difference between these two groups is the regularity with which they have taught physics in their careers supports the point made earlier that repeated experience over the years in preparing for and conducting classes in the subject can, at least partly, help compensate for limited academic background.

The importance of all this is underlined when we remember that high-school physics programs are generally very small, with over 80% having only one physics teacher at any given time. As a result, the situation of an individual teacher can have a profound effect on the physics experience, or lack of it, for a school's entire student body. The students of a teacher who feels well prepared and well supported have a very good chance of enjoying an exciting and stimulating introduction to physics. By the same token, a reluctant or poorly qualified teacher can discourage even enthusiastic students.

The data on professional association membership seems to follow neatly what would be logically expected from the specialization categories. Membership in the American Association of Physics Teachers (AAPT) is highest for physics specialists, lower for career teachers, and lower still for occasional teachers. On the other hand, membership in the broadly focused National Science Teachers Association (NSTA) is most common among the career teachers, who have their feet firmly planted in at least two disciplines (physics in terms of teaching experience and a different field in terms of academic training). The lower proportion of occasional teachers in the NSTA may be due to the greater likelihood of their belonging to the teachers' group for their area of specialization (say, math or chemistry). The proportion of each group's AAPT members who also hold membership in NSTA is similar, at around 50%.

Not surprisingly, given their greater likelihood of involvement in AAPT, we found that specialists tended to be more involved in physics-related professional development activities than career and occasional teachers. Perhaps reflecting their higher awareness of recent physics developments, specialists were also slightly more likely to have recently made changes to the topics covered in their introductory physics courses.

In the development of the specialization measure, we linked area of academic training with the number of years teachers reported having taught physics and a variety of other subjects. While this establishes an objective yardstick, it has a number of drawbacks: it does not indicate how *much* physics is taught by a teacher in a typical year, nor does it gauge the impact of recent experience, which may weigh more in shaping current identification. Most important, it does not get at the extent to which a teacher may subjectively identify herself with a particular subject.

We therefore also asked teachers to characterize their own sense of specialization across their career. As can be seen in Fig. 6, there is relatively close agreement between the two specialization measures. As would be expected, many of those who were classified as career physics teachers identified their specialization as being outside of physics, probably attributable to the fact that physics was

not their area of formal academic training. As for occasional physics teachers, the fifth who identified themselves as physics specialists may have only recently begun teaching physics regularly, or they may view themselves as physics specialists even though they are not given the opportunity to teach physics nearly as often as other subjects.

Another advantage of having the subjective measure is that we can use it for comparisons on items such as teaching experience that figured in the definition of the objective measure categories. This advantage also extends to items that are likely to be highly correlated with length of service, such as age and salary. Fortunately, as Table IV demonstrates, there is little evidence of bias due to the way our objective measure was defined. Those who saw themselves as physics specialists were virtually identical with nonspecialists in terms of age and seniority, and there were only small differences in salary levels and in the percentage with graduate degrees. One small—and expected—difference was that while nonspecialists had slightly more years teaching secondary school, specialists had spent more years teaching physics. Also, because of the traditional paucity of women majoring in physics, compared with the other sciences, it comes as no surprise that there are fewer women among the ranks of physics specialists, compared with nonspecialists.

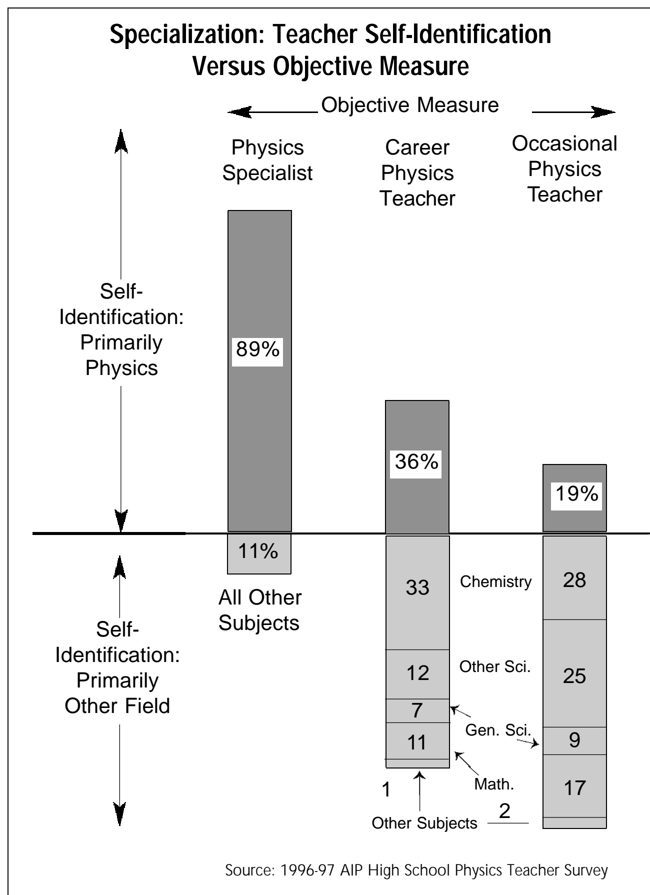

Fig. 6.

Recent Trends

There are hopeful signs that overall qualifications of physics teachers have been improving in recent years. The percentage of all teachers with a physics or physics-education degree has risen from 27% in 1990 to 33% in 1997. Among teachers in the first three years of their careers, the percentage with either type of physics degree rose from 24% in 1990 to 43% in 1997. In our sample, teachers with physics degrees were at least as likely as those without degrees to remain in teaching, implying that should this trend continue, we will see a rise in the overall percentage of teachers with physics degrees in upcoming years.

What could be behind the influx of better-trained teachers into physics teaching? As we alluded to earlier, even though the percentage of teachers able to specialize in physics teaching remains relatively low, the steady increase in overall physics enrollments—from 20% of all high-school seniors in 1987 to 28% in 1997—has meant that there has been a growing opportunity to specialize over the past few years. Along with this enrollment increase—and probably spurring it on—has been the broadening of the range of the types of physics courses offered, with movement away from the "one size fits all" regular physics into distinct conceptual, honors, and advanced placement courses, each geared toward students with different interests and levels of mathematics skills.[1]

This increase in enrollments has led to an increase in the percentage of physics teachers who have physics as their primary teaching assignment. Physics courses made up half or more of the teaching load for 41% of teachers in 1997, compared with 32% in 1987. For those with physics degrees, 63% now teach primarily physics. Additional evidence of this trend comes from recent AIP surveys of physics bachelor's degree recipients, which found that high-school teaching was the only career option open at that level that allowed extensive use of their physics training. Not only are more

Table IV. Teacher characteristics by subjective specialization category.

	Physics Specialists	Non-Specialists
Median age	44	44
Median years teaching secondary school	12	13
Median years teaching at current school	8	9
Median years teaching physics	10	7
% with graduate degees	64	53
Median salary (1997$)	$36,000	$32,000
% women	19	31
Number of respondents	1157	1247

new physics degree recipients being drawn into teaching, the improving conditions may help them to stick with the career as time goes on.

While high-school physics seems to be in pretty good hands, the same cannot be said for chances of quality physics exposure at the primary-school level. While hard data on physics background at this level are much harder to come by, all indications are that many teachers in earlier grades get only a meager introduction to basic physics concepts.[3] Few of the relatively advanced science students taking high-school physics have elementary education as their career goal. At the two-year college level, where many elementary-education majors start their postsecondary training, it is not uncommon for prospective automotive mechanics to be required to take physics, while future primary-school teachers are permitted to take a less advanced, single-semester "Physical Science for Elementary Education Majors" course that assumes only a minimal familiarity with basic algebra.

These studies and others have also found that inservice as well as preservice elementary-school teachers express the greatest anxiety over their preparation for teaching science, especially physics. It is not a big stretch to imagine how many students entering high school acquire their sense that physics is a subject suitable only for the brightest and most ambitious students, or for those who are science-oriented and college-bound. Until this self-reinforcing pattern is changed, it will be very difficult for high-school physics enrollments to maintain their present upward trajectory, and to transform physics from a topic of unfamiliarity and discomfort to a focus of wonder and curiosity for the majority of adults in the United States. It is at the primary, rather than at the secondary level, that concern over school teachers' physics background seems most appropriate.

References

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2. M. Neuschatz and L. Alpert, "Overcoming Inertia: High School Physics in the 1990's" (AIP, College Park, 1996).
3. See for example, I. R. Weiss, "Report of the 1985-86 National Survey of Science and Mathematics Education" (Research Triangle Institute, Research Triangle Park, N.C., 1987). Also publications of U.S. Department of Education, National Center for Education Statistics on the 1993-94 Schools and Staffing Survey and the 1994-95 Teacher Follow-up Survey.