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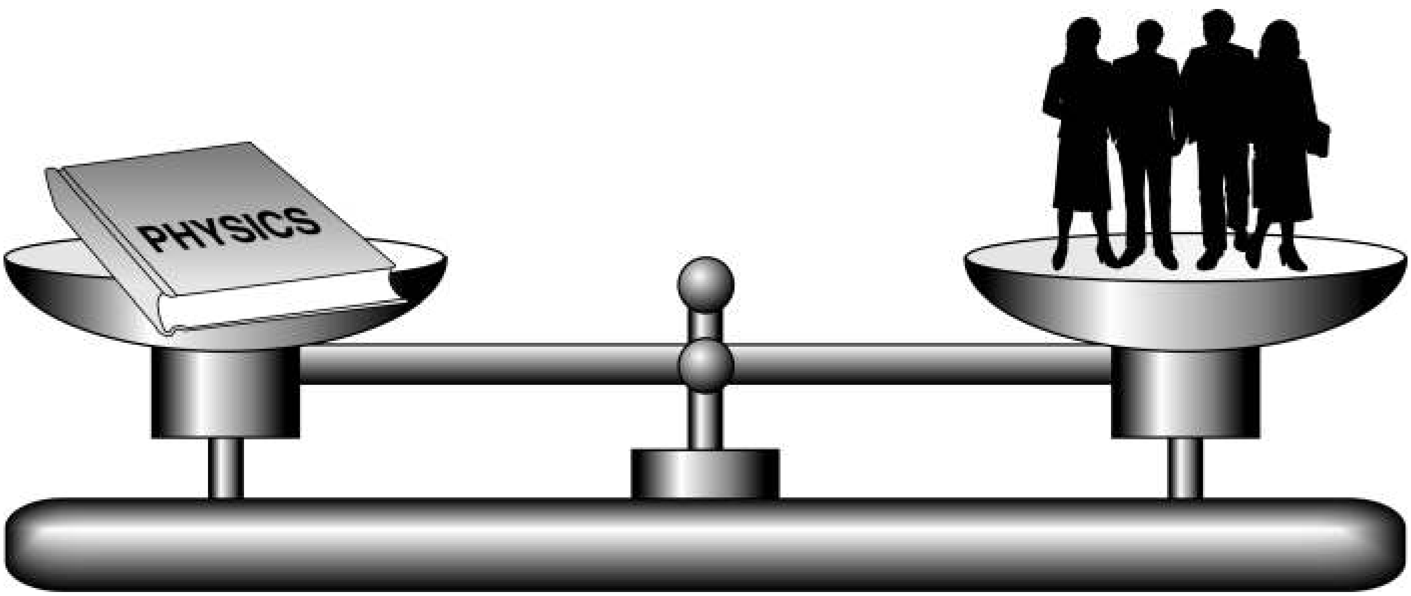
Reaching the Critical Mass



The Twenty Year Surge in High School Physics

Findings from the

2005 Nationwide Survey of High School Physics Teachers

by Michael Neuschatz, Mark McFarling, and Susan White

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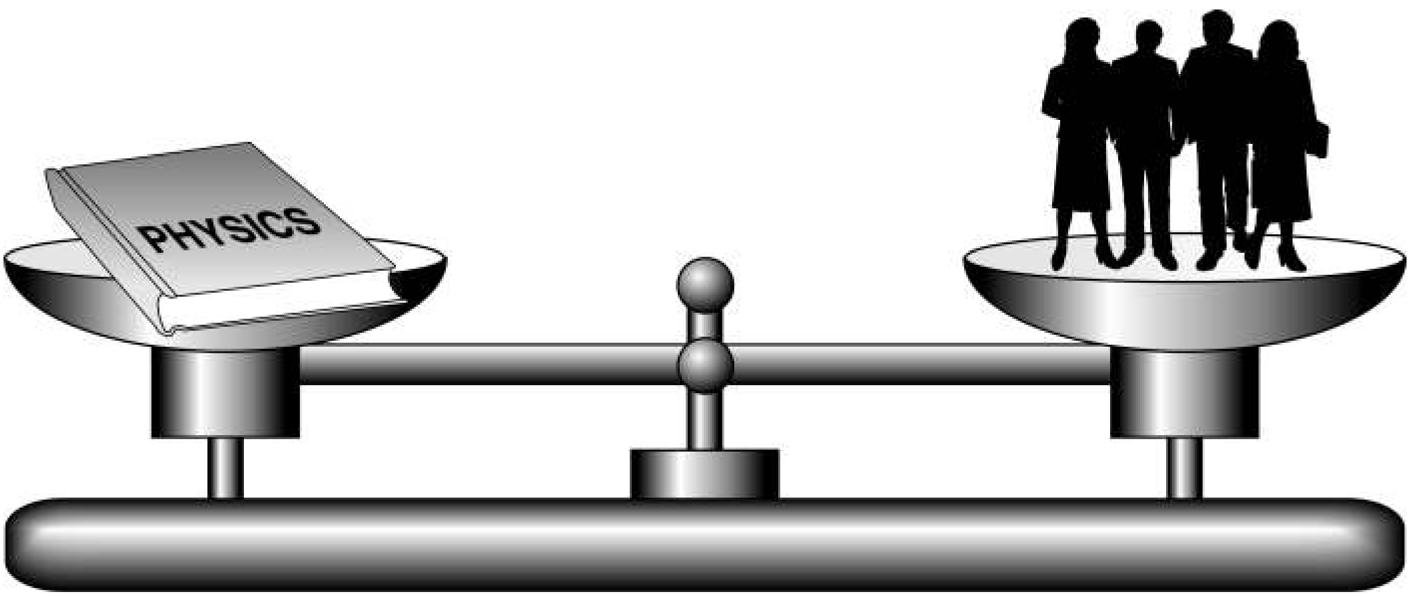

Findings from the

2005 Nationwide Survey of High School Physics Teachers

by Michael Neuschatz, Mark McFarling and Susan White

College Park, Maryland

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The findings in this report are the fruit of a collaborative effort of many individuals and organizations. Special thanks are due to the American Association of Physics Teachers and to the education administrators and school principals whose schools took part in the survey. As always, our deepest gratitude is to the physics teacher participants, whose generosity with their time and willingness to express their experiences and feelings made this study possible.

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HIGHLIGHTS

- Enrollments in high school physics continue to grow. In 2005, one out of every three high school seniors had taken at least one physics course before graduating. Twenty years ago this figure was one in five (**Figure 1**). In absolute terms, the number of students having taken physics during high school has almost doubled in fifteen years, from about 620,000 students in 1990 to 1.1 million in 2005.

- In 2005, there were about 23,000 high school teachers who taught at least one physics class. This was up from 17,900 in 1987. This increase of 28%, while not negligible, is far smaller than the growth in the number of students. Because the average class size has remained stable at 18 students, the faster growth in the number of students translates into more classes per teacher. This has led to an increase from 28% in 1987 to 44% in 2005 in the proportion of teachers who had all or most of their class assignments in physics (**Figure 8**).

- The number of students taking an honors, AP, or second-year course has almost tripled, growing from about 106,000 in 1990 to about 308,000 in 2005 (**Figure 6**). Some of the increase is attributable to helpful trends in population and college attendance, but it has likely been further spurred by energetic and creative efforts to promote refinement and reform.

- Over 70% of those teaching physics possess either a physics degree or extensive physics teaching experience, or both (**Figure 9**). Among those with no physics degree and little teaching experience, roughly two-thirds have degrees in another science field.

- Among students, no longer is high school physics predominantly a preserve of white males. In terms of overall enrollment, female students have reached near parity (**Figure 3**). In addition, underrepresented minorities have made great strides, especially in the last dozen years, towards closing the historical gap in enrollment (**Figure 5**).

- The movement to promote the idea and encourage the implementation of Physics First (PF) has been slowly but steadily gaining ground over the last several years, but the actual spread of the practice has been more modest. We estimate that 4% of all U.S. high schools – 3% of all public and 8% of all private schools – had implemented some variant of Physics First by 2005. Overall, teachers' opinions regarding the efficacy of the Physics First approach are little changed from 2001, with a majority still opposed. However, over 70% of those participating in a PF curriculum had positive opinions about it (**Figures 17, 18**).

- More than 80% of public school teachers feel that the testing and teacher qualification provision in the No Child Left Behind (NCLB) legislation has not affected them or their physics classes and curriculum. Of those reporting an impact from the testing or teacher qualification provisions of NCLB, more than two-thirds view it as negative (**Table 8**).

- Funding available per class for equipment and supplies has fallen from about $300 in 1987 to about $250 in 2005. After adjusting for inflation, physics teachers have less than half of the funds available to support the purchase of equipment and supplies than they did twenty years ago (**Figure 16**). In terms of starting salaries, the picture is slightly better with the growth in salaries outpacing inflation by about 0.8% per year (**Figure 20**).

- An examination of textbook use reflects the ebb and flow that naturally occurs as publishers introduce and periodically revise their offerings. The top four texts account for over 85% of the teacher/school system adoptions in the regular first-year physics course. The choices for honors physics courses vary more widely (**Table 1**).

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I. INTRODUCTION

The recent political landscape of the United States is no stranger to reports and proposals addressing "our worsening educational crisis." Most of them had catchy names, warned of impending disaster, urged dramatic steps in a relatively short timeframe, and have now been superseded or put aside. Twenty-five years ago, the National Commission on Excellence in Education's *A Nation at Risk* warned that our country's global economic pre-eminence was being undermined by a mediocre educational system. Within a few years, a broad movement emerged to develop National Education Standards, which later engendered separate state standards. Thousands of hours of discussions and hard work were invested in developing these standards; yet they are now facing growing calls for surgery. In 1989, the nation's governors met to pledge that our students would be first in the world in science and mathematics by the year 2000. Yet, just two years ago, the nation was again warned that only by revamping science and math teacher training could we *Rise Above the Gathering Storm*. The National Science Foundation argued for and tried to spark systemic reform of educational systems, and, of course, the Department of Education weighed in with *No Child Left Behind*.

Far from committee rooms and task force meetings, life and learning went on. There continue to be deep-seated and persistent inequalities, overlapping and often competing layers of administration and planning, and a kaleidoscope of contending educational philosophies and pedagogical approaches. The United States is still not first in the world in student learning, but it very well may be first in the complexity of its educational systems and in the number of studies launched to examine its failings.

However, there are some exceptions, and this report is about one of those. High school physics education has been a genuine bright spot. There are some clear and verifiable gains, first and foremost in the fraction of students who simply take a course in the subject before they leave high school. And there are gains in the increasing diversity of students entering physics classes and in the range of courses offered, especially those designed to meet the needs of students traditionally left out of high school physics altogether. The recent growth in the number taking physics has also been bolstered by helpful trends in population and college attendance, and further spurred by energetic and creative efforts to promote refinement and reform.

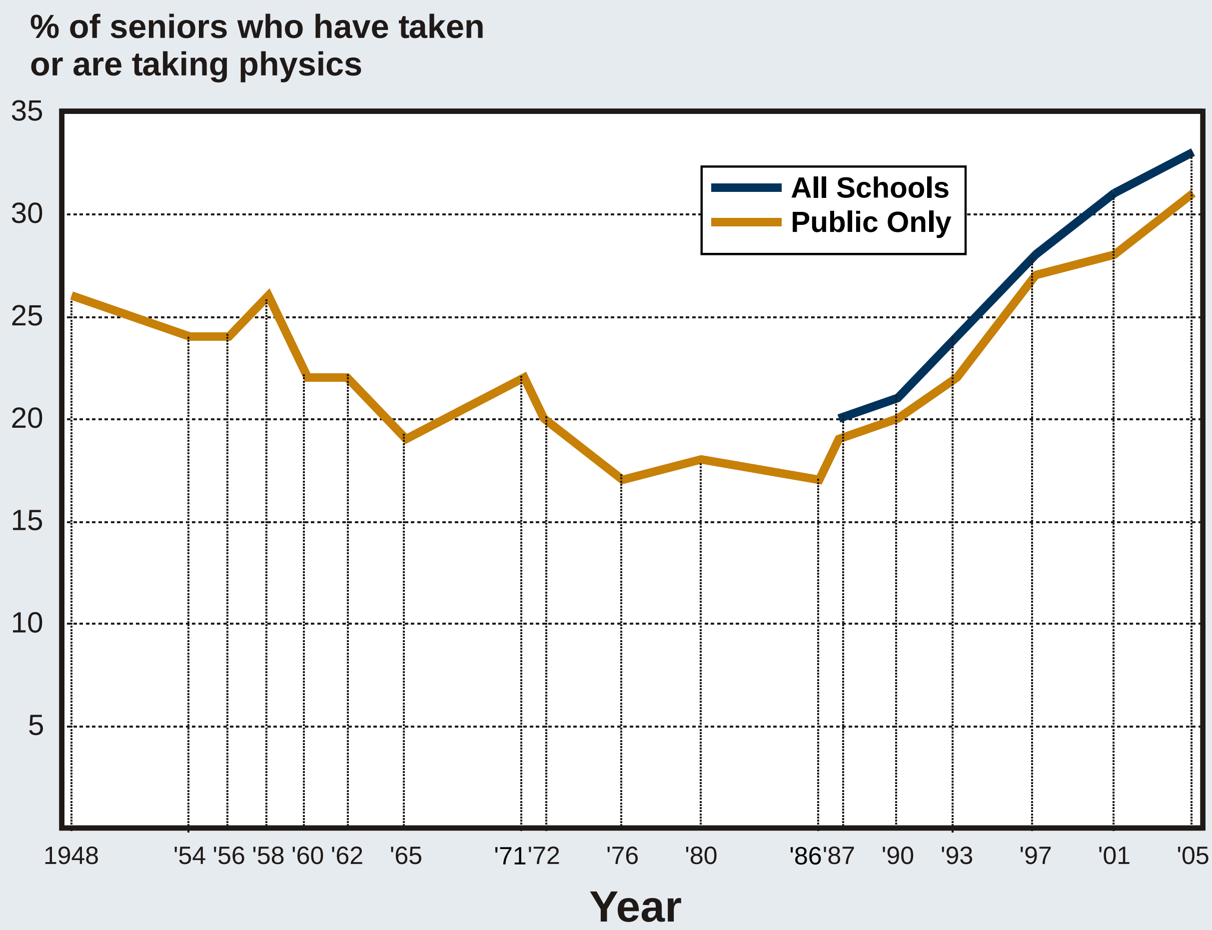
This good news will be readily apparent in the tables and figures that appear throughout this report. They show that, during the past two decades, there has been a sea change in the place of physics in secondary-level education across the United States. When the American Institute of Physics conducted our first Nationwide Survey of High School Physics Teachers during the 1986-87 school year, we found that only 20% of all high school students took a physics course by the time they graduated (see **Figure 1**), and that, largely because of the low enrollment, fewer than 30% of all physics teachers had their primary teaching assignment in physics. Also due to the small number of students, while almost all except the very smallest schools offered physics, four-fifths of those schools offered only one version, the traditional introductory algebra-based course.

Twenty years on, substantial changes in each of these areas have emerged, stimulating many other shifts. The resulting big picture is encouraging – physics is no longer the almost exclusive province of future college science, math and engineering majors. More and more, college-bound students interested in other fields, including the social sciences and humanities, are taking high school physics in substantial numbers. The proportion taking physics has climbed steadily, to the point that one-third of all high school students have taken it by graduation. In several states, the fraction now exceeds half. And no longer is high school physics predominantly a preserve of white males. In terms of overall enrollment, female students have reached near parity, and underrepresented minorities have made great strides, especially in the last dozen years, towards closing the historical gap in enrollment.

But for all these changes, not all the news is positive. While there has been notable overall progress, detailed below, in addressing gender and racial disparities in enrollment, significant differences persist. For example, the last time we examined course enrollment by gender and racial group, about a decade ago, we found significantly greater disparities in the advanced physics courses, like Advanced Placement and second-year physics, than in regular physics. More recent data from the College Board on advanced placement test takers suggest that this pattern still holds in physics. These disparities are amplified at higher academic levels, where, despite recent gains, men still outnumber women by more than 3 to 1 among college physics majors, and minority physics majors remain woefully scarce.

While there has been progress on gender and racial gaps in high school physics enrollments, there are two other areas we have discussed in previous reports where little movement can be detected. These are the distinct but overlapping factors of social class and academic orientation. In prior studies, schools which teachers identified as having, on average, an economically disadvantaged student body displayed far lower physics enrollments than schools with students who were described as being more advantaged. Similarly, national longitudinal studies of educational outcomes have

Figure 1. Physics Enrollment in U.S. High Schools, 1948-2005



AIP Statistical Research Center: 1986-87, 1989-90, 1992-93, 1996-97, 2000-01 & 2004-05 High School Physics Surveys; Pallrand et al. (1985); Dept. of Education., Nat'l Center for Education Statistics (Various Years)

repeatedly shown that students who end up in the labor force or at two-year colleges after high school are far less likely to have taken high school physics than those who go to four-year colleges or universities. Both of these topics will be addressed in detail in a later section of this report.

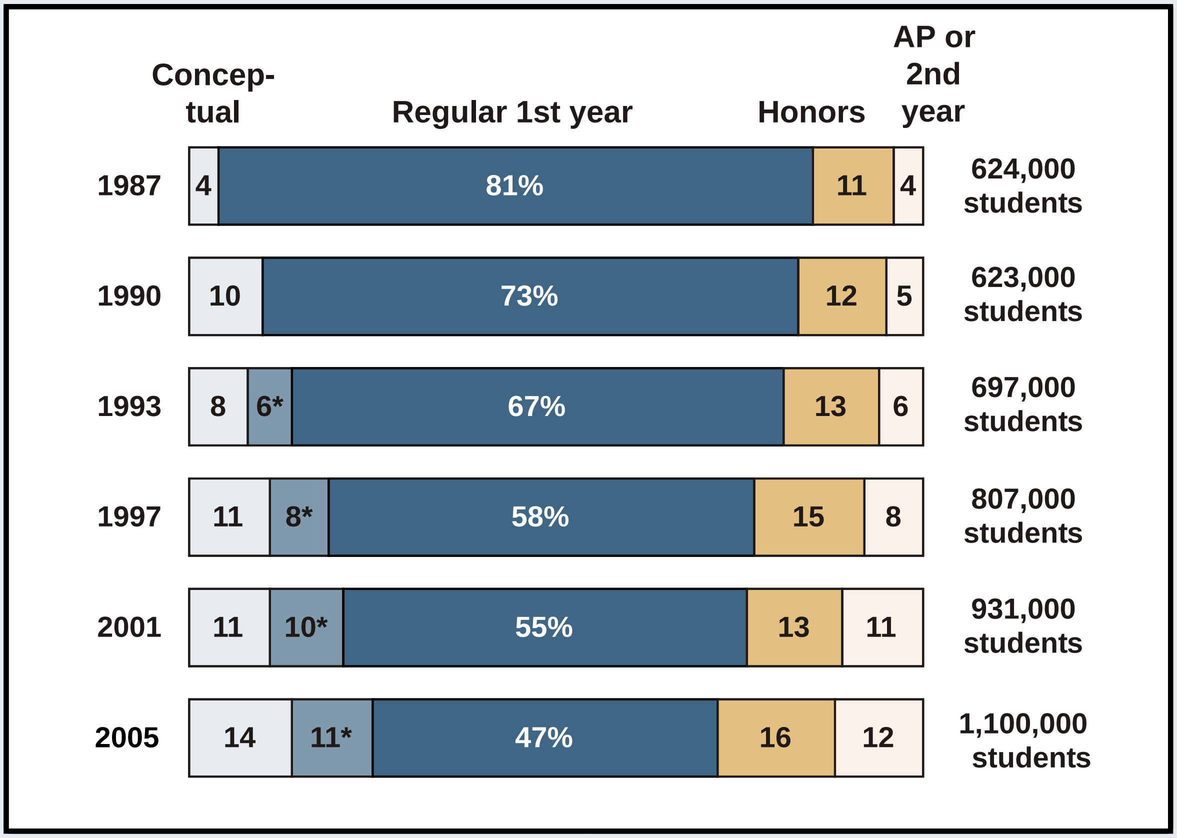
The slow but steady progress that has been achieved in some areas, and the disparities that persist in others, are symptoms of an enormous and enormously complex educational system. Literally thousands of academic policy-setting and administrative units span the geographical and social fabric of this country. Many of these bodies cross divides of rural and urban, rich and poor, black and brown and white, as well as local, state and regional boundaries. Often the various entities do not act in concert with each other, proffering mandates that are not complementary at best, and are in direct opposition at worst. In an educational and societal culture that proclaims the equality of all under the law, schools have historically been a place of separation. Thus, while almost all public school students are channeled towards a nominally equivalent high school diploma, the geographical base of the local school tends to generate student bodies that reflect neighborhood differences. Since funding rests partly on local property taxes, these disparities are frequently reproduced in the schools themselves. In addition to external variations, there are often internal differences, too, with separate classes and curricula for the college-bound and the non-college bound. These distinctions, in turn, set students on paths towards different personal and social destinations. These paths may veer off the common track in individual cases, but they still ultimately predict general outcomes for most students.

II. STUDENT CHARACTERISTICS

Twenty years ago, the world of high school physics was much simpler than it is today. Although alternative versions of the basic course had been introduced, one "flavor," commonly described as the traditional algebra and trigonometry-based first year introductory course, clearly predominated (see **Figure 2**). And the students who took that course were also considerably more homogeneous in those days – mostly male, primarily science- or technology-oriented and college-bound, and largely white.

While some of this description would still hold today, there have been some significant changes in the demographics of high school physics. For one thing, while physics students are still more than half male, females approached parity in overall enrollments by the late 1990's, and have remained there since (see **Figure 3**). Still, as noted earlier, significant differences by gender still seem to persist beneath the surface. Prior to the 1980's, there was but one dominant physics course typically leading towards further science and technical study in college, and earlier research had shown that male students far outnumbered females in physics classes (Brown, Obourn, and Kluttz, 1956; Welch, 1969). In the late 1980's, our own studies, disaggregated by course type in response to the emerging curricular differentiation, found that enrollment of girls was moving towards parity in the basic introductory course and in physics courses aimed at non-science students. At the same time, the gender gap in more advanced physics classes remained quite large. Even this

Figure 2. High School Physics: Enrollment Distribution



*** Percent of students in regular first-year physics courses that use conceptual physics textbooks.**

AIP Statistical Research Center: 1986-87, 1989-90, 1992-93, 1996-97, 2000-01 & 2004-05 High School Physics Surveys

disparity eased in the 1990's, according to figures on AP physics test takers made available by the College Board. But since the late 1990's, these gains seemed to have largely stopped (**see Figure 4**). So, in a sense, for all the progress, we still find ourselves in a familiar place – while there is now more variety in the course offerings and more variety in the students enrolling in them, men still outnumber women in the courses aimed at those planning further study in physical science and engineering in college.

If the growth in physics enrollments from the mid-1980's to the mid-1990's was due in part to the growing presence of girls in physics classes, that trend softened as girls approached parity, and a new source of increase emerged. Minority students, especially African-American and Hispanic students, had long been woefully underrepresented in high school physics. But from 1990 until 2001, the percentage of students from these groups who took high school physics more than doubled (see **Figure 5**), with the fastest increase

Figure 3. Females as a Percentage of Total Enrollment in High School Physics

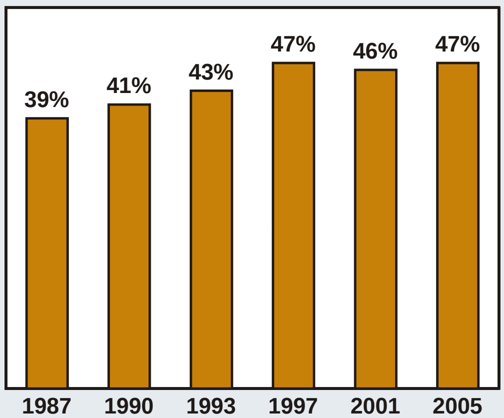


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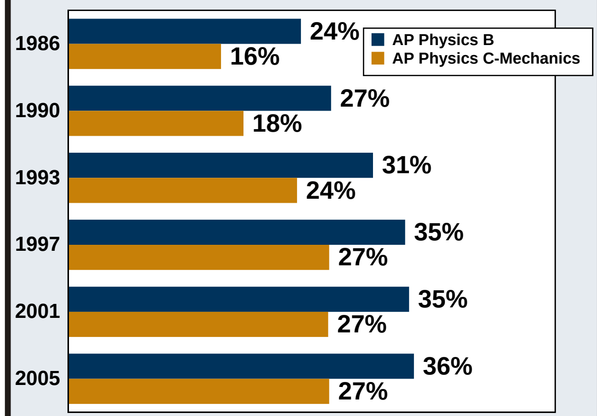
Figure 4. Females as a Percentage of AP Physics Test Takers



College Board Data Compiled by AIP Statistical Research Center

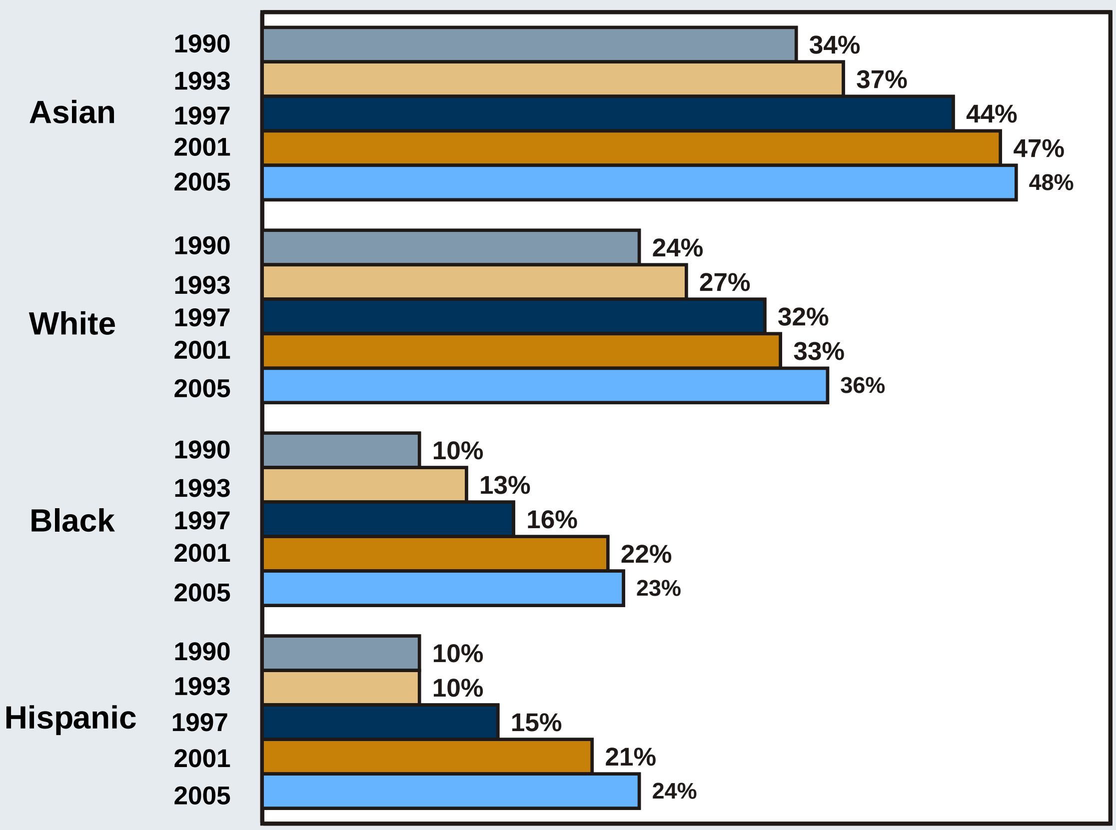
occurring during the latter part of that interval.

Coupled with the increasing share of these groups, especially Hispanics, among the broader high school population, this growth accounted for a significant portion of the jump in physics enrollments during this period. An additional source of increased enrollments was the growing numbers of Asian-Americans in the US student population, with their historical pattern of taking physics at a higher-than-average rate. However, in the latest survey, enrollment rate increases among these groups appear to have eased somewhat. If this continues, it may present a challenge for maintaining the rising trend in overall physics enrollment rates, as groups with traditionally lower physics-taking continue to increase their overall share of the student population. This is especially the case with Hispanic students. By 2005, 45% of the students younger than 5 were minorities according to the US Census Bureau (Bernstein, 2006). In many western states of the US, the percentage of "minority" students combined exceeded 50% in all public school grades in 2005, and other regions were forecast to follow in the upcoming years.

III. CURRICULUM

The role that the broadening of the physics curriculum has played in the growth of high school physics enrollments and the inclusion of groups of students that were previously underrepresented in the physics classroom should not be underestimated. The extent of the change can be seen graphically in **Figure 2** (on **page 5)**. Here we can clearly see the evolution of course offerings from a largely "one-size-fits-all" approach to an array of courses that try to address the needs of students in different academic streams and with different sets of interests. As Figure 2 shows, the greatest growth has been in the category labeled conceptual and in courses labeled regular 1st year physics that use textbooks and other materials designed for a conceptual approach. Together these two categories now comprise more than 25% of all physics

Figure 5. Percent of Students in Each Racial Group Taking Physics



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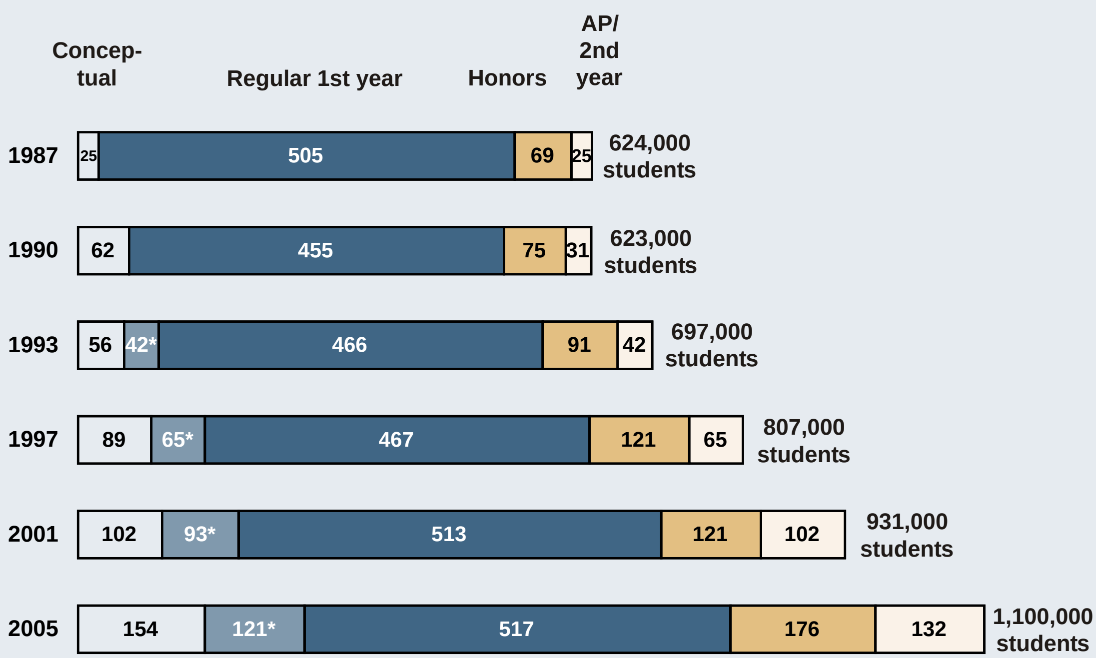
enrollment, and have tripled in absolute numbers just since 1993 (see **Figure 6**). This reflects what appears to be an ongoing fundamental change in the place of physics in high school, as it expands to become a common part of the academic preparation for most students heading towards four-year colleges and universities after high school graduation, regardless of orientation or anticipated major.

There is little evidence that the growth of conceptual courses has impinged on the size of enrollments in the more traditional algebra- and trigonometry-based course. Since 1987, enrollment in the latter has more than held its own, while honors physics enrollments have grown by 150% and AP enrollments have soared more than five-fold. This is strong evidence of a positive feedback loop – greater enrollments, especially beyond a critical minimum point in individual schools, can facilitate more diverse course offerings, including courses designed to meet the needs of a broader range of students, and these in turn may attract more students, reinforcing the initial trend.

Yet, there seems to be a limit to this "virtuous circle." More students are heading to four-year college programs than ever

Figure 6. Students Taking High School Physics by Type of Course

(Number of students, in thousands)

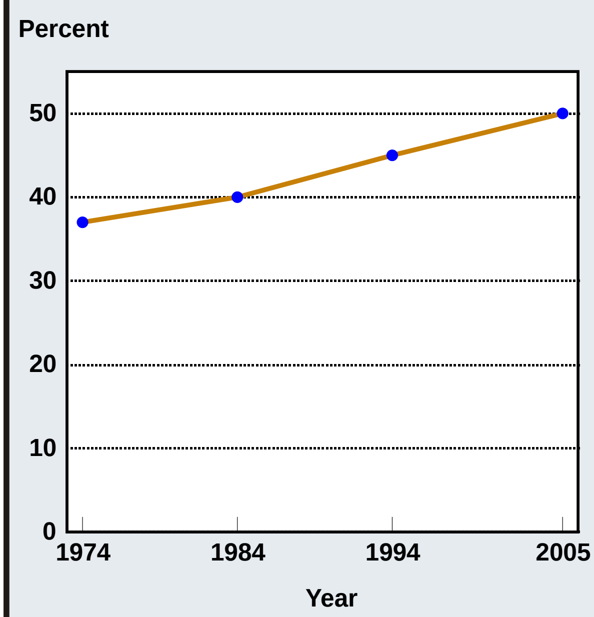


*** Number of students in regular first-year physics courses that use conceptual physics textbooks.**

AIP Statistical Research Center: 1986-87, 1989-90, 1992-93, 1996-97, 2000-01 & 2004-05 High School Physics Surveys

before, rising steadily from 37% in 1974 to 50% in 2005 (NCES, 2008). (See **Figure 7.**) However, galloping physics enrollment increases seem to have largely missed other students, including those going on to two-year colleges and those heading directly into the labor force after graduation. A Department of Education study showed that only 20% of those heading to two-year colleges and 6% of those going into the workforce took high school physics (NCES, 2000). These students could be seen as the new frontier of high school physics enrollment, and more data will be presented on this below.

Figure 7. Percent of High School Graduates Enrolling in Four-Year College



US Dep't of Education, 2006 Digest of Education Statistics

There are underlying trends and forces that could help push enrollments beyond the current total. For one thing, many states are continuing to raise graduation requirements, and some of these changes may encourage or even mandate that students take physics. Another initiative that would produce a similar outcome is a movement requiring that all ninth graders take physics, typically taught using the conceptual approach. This idea has become popular with a growing number of teachers and educators, primarily among private schools but recently in public as well, including a handful of entire districts. (This topic will be examined in more detail in **Section VI**.) To the extent they take root and spread, these efforts may result in enrollments that continue to rise, and to spread both to the remaining groups of college bound students who are humanities and social science oriented, and also to the even larger group of students who enter two-year colleges or the workforce after graduation.

Not surprisingly, changes in curriculum also foster changes in textbooks and other course material most commonly employed in physics instruction. Over the years that we have conducted this study, the line-up of textbooks used in high school physics courses has been repeatedly reshuffled, as the major publishers introduce and periodically revise their offerings. **Table 1** documents the ebb and flow of the most widely-used texts by the type of course in which they are most commonly found. In the regular first-year course, the initial favorite from the first survey we conducted, Holt's *Modern Physics*, was supplanted by Merrill-Glencoe's *Physics: Principles and Problems*, which is now being challenged

Table 1. Most Widely Used Physics Textbooks

	Percent of teachers using this text in:						% rating text high in quality**
	'05	'01	'97	'93	'90	'87	
Regular first year physics	%	%	%	%	%	%	%
1. *Physics: Principles & Problems* (Zitzewitz / *Glencoe-McGraw*)	40	49	53	44	42	33	46
2. *Conceptual Physics - HS Level* (Hewitt / *Addison Wesley*)	16	13	13	9	*	*	59
3. *Holt Physics* (Serway & Faughn / *Holt*)	25	13	—	—	—	—	49
4. *Physics: Principles with Applications* (Giancoli / *Prentice Hall*)	5	—	—	—	—	—	62
5. *Modern Physics* (Trinklein / *Holt*)	*	5	20	23	32	36	53
Conceptual physics							
1. *Conceptual Physics - HS Level* (Hewitt / *Addison Wesley*)	76	75	74	79	75	27	69
2. *Active Physics* (Eisenkraft / *It's About Time*)	5	—	—	—	—	—	20
3. *Physics: Principles & Problems* (Zitzewitz / *Glencoe-McGraw*)	*	6	7	8	7	28	29
Honors physics							
1. *Holt Physics* (Serway & Faughn / *Holt*)	26	9	—	—	—	—	61
2. *Physics: Principles & Problems* (Zitzewitz / *Glencoe-McGraw)*	18	30	25	18	*	*	46
3. *Physics* (Giancoli / *Prentice Hall*)	17	16	19	14	10	7	73
4. *College Physics* (Serway & Faughn / *Brooks-Cole)*	8	9	*	—	—	—	65
5. *Physics* (Cutnell & Johnson / *Wiley*)	8	7	*	—	—	—	76
6. *Conceptual Physics - HS Level* (Hewitt / *Addison Wesley*)	6	6	*	*	*	*	52
7. *Modern Physics* (Trinklein / *Holt*)	5	*	15	20	27	28	55
8. *College Physics* (Wilson and Buffa / *Prentice Hall*)	5	—	—	—	—	—	57
Advanced Placement B							
1. *Physics: Principles with Applications* (Giancoli / *Prentice Hall*)	35	33	27	28	—	—	73
2. *College Physics* (Serway & Faughn / *Brooks-Cole)*	20	25	24	10	—	—	87
3. *Physics* (Cutnell & Johnson / *Wiley*)	19	15	9	—	—	—	68
Advanced Placement C							
1. *Fundamentals of Physics* (Halliday, Resnick & Walker / *Wiley*)	45	47	41	39	—	—	73

*less than 5% **On a scale of 1 to 5, with 5 the highest quality rating, the percent rating a text as a 4 or 5. — not separately rated

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by Holt's new offering, which has also taken the lead in honors physics classes. In the other types of courses, there are fewer major changes since our last survey in 2001. In physics for non-science students, Hewitt's high school level *Conceptual Physics* text continues its almost total dominance, while it continues to make small inroads in the traditional algebra- and trigonometry-based introductory classes as well. In Advanced Placement physics classes, Giancoli's text continues to be the most widely-used for the algebra-trig-based AP-B course, while the newest edition of the original Halliday and Resnick text continues its decades-old dominance for the calculus-based AP-C course. Curiously, while most of these most popular texts continued to get favorable ratings from a majority of respondents using them, we note a small but definite drop in the ratings for many of them compared to four years earlier.

IV. WHO'S TEACHING PHYSICS?

The expansion of high school physics over the past two decades has encompassed major changes in both the variety of physics courses offered number and the composition of the students who take these courses. These transformations have belatedly begun to generate significant changes in the size, circumstances and experiences of the corps of physics teachers as well.

In terms of size, the overall number of teachers with at least one physics class has continued to rise steadily, reaching 23,000 in 2005, up from 17,900 in our first study in 1987. However, while this 28% gain is not negligible, it is far smaller than the 77% rise in the total number of students taking physics. Part of the reason for the slower rise may be the difficulty of hiring new teachers, due to the long-standing shortage of qualified physics teachers, which we will discuss in detail below. What is important here is that the difference between these two growth rates has given rise to an important emerging change in teaching assignments. Given the fact that physics class size has remained stable (the average was 18 in 1987 and was the same in 2005), the only way that the rising number of students can be accommodated is through an increase in the average number of physics classes taught by each teacher.

While this may not, at first blush, seem an important development by itself, a look at previous findings from our studies suggests that this is indeed a critical change, capable of spurring a major culture shift among the ranks of high school physics teachers. This is because, historically, physics enrollment was so small that, unlike most other subjects, including the other major high school sciences, only a small minority of physics teachers were able to specialize in the field. In 1987, when we conducted our first survey, only a bit more than one in four (28%) teachers with physics classes had the majority of their class assignments in physics. This was clearly the product of low enrollment, since, in that same year, more than half of all U.S. high schools offered only one class in physics, and three-fourths offered one or two, still not enough to support even a single specialist teacher. As a result, most teachers of physics, regardless of academic training and career background, necessarily had to specialize in another field.

In these circumstances, few prospective teachers are willing to concentrate their preparation in physics, since most will be required to teach more classes in other fields. Indeed, it was the recognition of this situation that historically prompted education authorities in virtually every state to create a credential for “physical science” teaching, or even “broad science” teaching. In these circumstances, many science teachers concentrated their science coursework more in chemistry or biology, with a smaller number of physics credits, and then were assigned by their schools to teach physics on an as-needed basis.

The impact of the rising number of physics classes offered per school on this state of affairs has been fairly dramatic. Of course the objective shortage of physics teachers has remained and perhaps even worsened with the increase in student enrollments over the past twenty years. But, at the same time, the percentage of teachers focusing entirely on physics in a given year has doubled from 13% to 26%, and the percent teaching more physics than other subjects similarly rose from the previously-cited 28% to 44% (see **Figure 8**). However, when we broaden the definition of specialization to include academic training and experience over the years, the percentage who are specialist and career teachers has remained fairly stable (see **Figure 9**).

The cumulative effect of teaching more physics can be seen even more clearly in the response to our question asking teachers for their subjective view of which subject they specialized in. Here teachers take into account their sense of identity, as well as their academic background and their career-long experience with physics. They may also tend to put more weight on their recent years’ class assignments. In 1990, when we first introduced the question, 42% said physics was their specialty. By 2005, this had risen to 57%, a substantial rise in 15 years (see **Figure 10**).

Some demographic characteristics also showed evidence of change, while other aspects of teachers’ background displayed greater stability (see **Table 2**). One factor

Figure 8. Place of Physics in Current Teaching Assignment

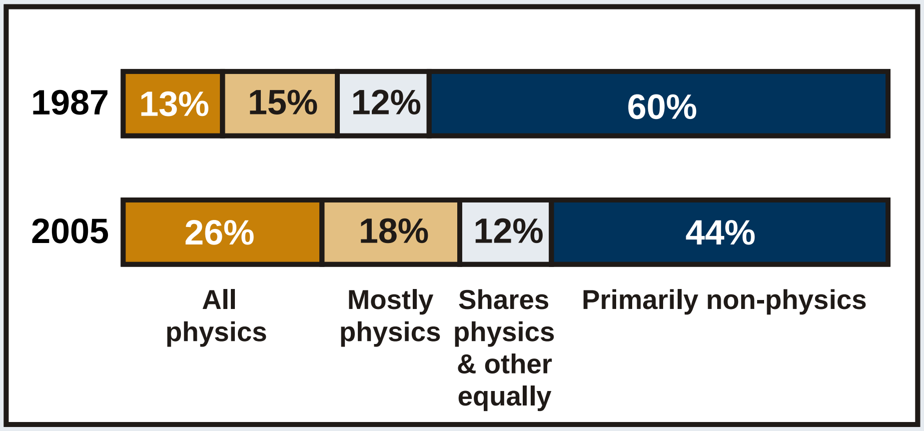

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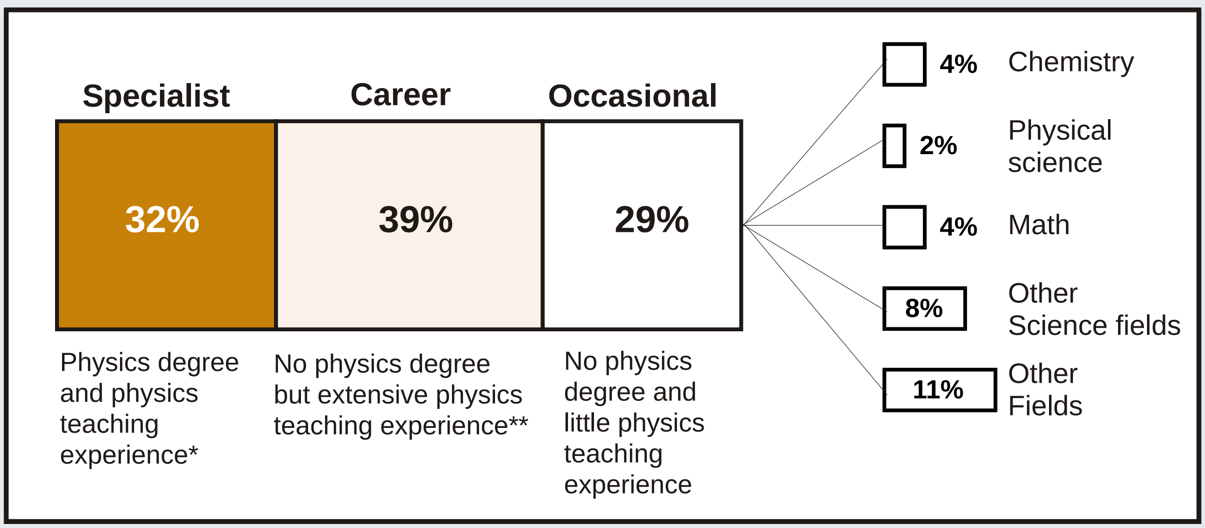
Figure 9. Teacher Specialization: Academic Training and Experience



*Teachers with physics degrees but insufficient physics teaching experience are excluded from this figure (3%).

**Career physics teachers include those who have taught physics as much as, or more than, any other subject, or have taught it for ten or more years. The distribution of highest degree earned by career teachers was spread evenly across the sciences, with 25% in math or engineering, 23% in biology, 17% in chemistry, 18% in other science fields and 17% in other fields.

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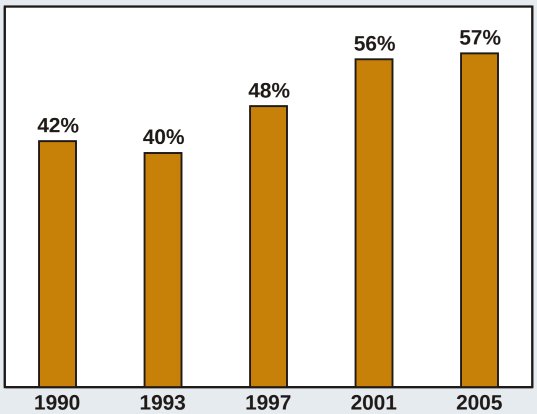
Figure 10. Percent of Teachers Describing Themselves as Specializing in Physics Teaching*



*Teachers reporting physics as their primary area of specialization.

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that has figured prominently in fears of teacher shortages has been the advancing age of the teaching corps, and indeed, in physics, the median age of respondents has risen slowly but steadily in the two decades that we have been conducting these surveys, from 41 to 46 years old. Yet, curiously, years of experience teaching physics has remained virtually unchanged during the entire interval, at around 9. Since it is unlikely that teachers have been, on average, taking significantly more mid-career leaves of absence than was the case 15 or 20 years ago, the most likely explanation is that newer teachers have, on average, begun their teaching career later than was the case 20 years ago.

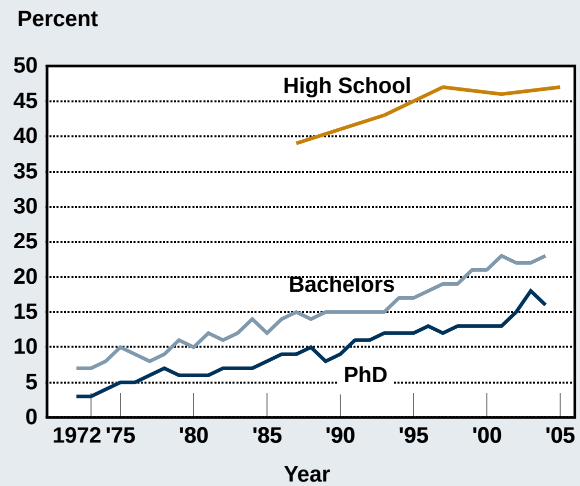
Table 2. Teacher Demographic and Academic Background in all Six Survey Years

	2005	2001	1997	1993	1990	1987
Number of physics teachers in sample	3,756	3,444	3,548	3,374	3,341	3,301
Response rate (%)	62	63	76	73	70	75
Median age (years)	46	46	44	43	43	41
% Women	30	29	25	23	22	23
AAPT membership (%)	23	24	25	29	26	24
Degree level (%)						
Bachelor's	34	35	42	38	38	37
Master's	60	60	54	58	58	59
Doctorate	6	5	4	4	4	4
Any physics degree (%)	33	33	33	29	27	26
in physics (%)	23	22	22	18	19	—
in physics education (but not physics) (%)	10	11	11	11	8	—

AIP Statistical Research Center: 1986-87, 1989-90, 1992-93, 1996-97, 2000-01 & 2004-05 High School Physics Surveys

The only direct confirmation we have of this is that, for the years that we conducted the study, there is evidence of a steady increase in the age of *starting* teachers. For first year teachers, median age was 25 in 1987 and 30 in 2005. The explanation may be in one or both of two possible trends: the tendency to take longer in college, and the possibility that more people are taking up teaching after starting off in or even completing another career. Further evidence for this conclusion will be presented in Section VII. A more minor contribution to the rise in median age without a concomitant rise in years of teaching experience may be the increase of women among physics teachers, combined with the tendency of some female teachers to take leaves of absence for childbirth or while their children are very young.

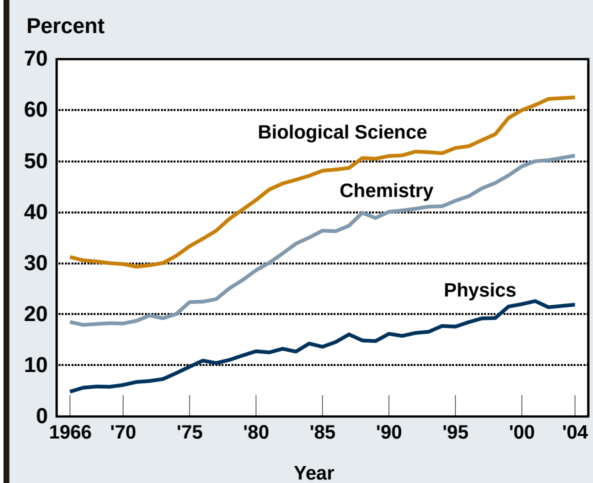
Figure 11. Representation of Women Among Physics Students at Different Academic Levels, 1972-2005



AIP Statistical Research Center: Enrollments and Degrees Reports

Women and Minority Representation

Figure 12. Percent of Bachelor's degrees earned by women in selected fields, 1966-2004

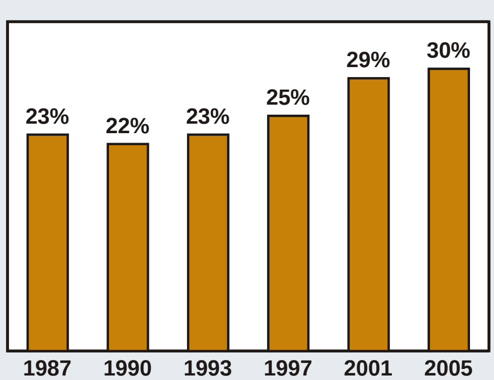


NSF, compiled by AIP Statistical Research Center

This brings us to the broader issue of the historically low level of women among physics teachers. This situation paralleled, and in part arose from, the paucity of women throughout physics, including as students in undergraduate and graduate courses and programs, from which high school physics teachers were likely to come. The situation is especially marked for physics specialists. As **Figure 11** shows, it is only in recent decades that women have reached an appreciable presence in post-secondary physics. And as **Figure 12** reveals, even among the sciences, physics is one of the disciplines where women have the lowest representation. This traditional predominance of male students in college physics classes also probably reinforced the just-mentioned paucity of women teachers among the other science specialists whose coursework might have made them prone to volunteer or be drafted into teaching physics where a physics specialist was not available.

However, along with the recent rise in the proportion of women at all levels, from high school to graduate school, in physics and related sciences, their presence among the ranks of high school physics teachers has also risen appreciably, especially since 1993 (see **Figure 13**). Moreover, while the causes of this rise are somewhat distinct from the longer-term trends that have raised the overall presence of females in high school physics enrollments to near-parity, the presence of more women teachers may encourage more female high school students to consider further study in physics as a viable option.

Figure 13. Percent of High School Physics Teachers who are Women



AIP Statistical Research Center: 1986-87, 1989-90, 1992-93, 1996-97 2000-01 & 2004-05 High School Physics Surveys

In contrast, despite the rise in the proportion of minority-group members taking high school physics, there has been almost no change in the very small proportion of their teachers who come from these same groups. African-American and Hispanic teachers each make up only one-and-one-half per cent of the total, not significantly different from the proportion they represented 18 years earlier. Some of the same factors that keep minority representation low in undergraduate and graduate-level physics even in comparison to many of the other science disciplines may be at work here. Still, Asian-Americans, who have historically been over-represented among physics students at all levels, account for only 2% of high school physics teachers. Another factor limiting the proportion of minority physics teachers may be the frequently-cited availability of far more attractive career choices for physics and other science majors, combined with especially vigorous recruiting of qualified minority candidates to fill these slots.

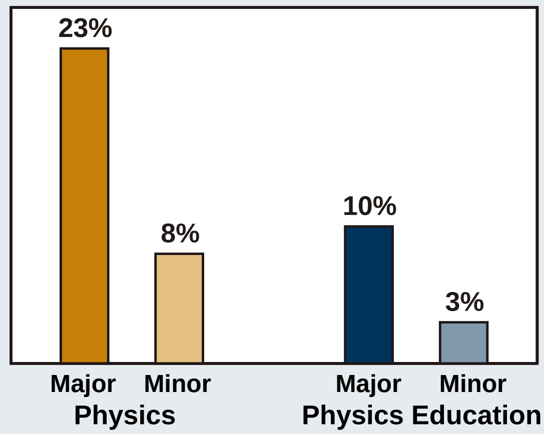
Academic Background and Professional Development

Another area where little change can be seen is in the proportion of physics teachers with formal academic degrees in the field. There is a rise in the percentage of physics teachers who consider themselves as specialists in the field, which we noted was at least partly based on the current and recent years' teaching assignment. However, when we look strictly at formal academic preparation, we find that there has been very little actual increase in the number of physics teachers who have majored in physics or physics education. As **Figure 14** shows, only 23% of physics teachers hold a college degree in the field, with another 10% reporting a degree specifically in physics education.

This combined 33% is right in-line with what we found in 1997 and 2001, and only slightly better than earlier results. It is possible that rising high school physics enrollments and the consequent greater chance of concentrating on physics teaching may spur more college students interested in pre-college science teaching to choose physics as their major field, but there is certainly no guarantee that this will occur. In addition, frequent change in the rules governing credentialing, as in the recent No Child Left Behind Act to be discussed in greater detail below, can have a powerful impact on academic preparation and career choices.

Because graduation from a formal physics major characterized only a minority of physics teachers, we have always focused as well on more informal measures of background and qualifications. For example, each time we have done the survey, we have asked teachers, independent of formal education, to assess

Figure 14. Percent of Physics Teachers with a Physics Degree



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various aspects of their own preparation to teach physics. The responses in 2005 (see **Table 3**) were largely on a par with the previous round, with a slight drop in the proportion judging themselves as "very well prepared" in their knowledge of basic physics and other science concepts. On the other hand, there was a continuation of the modest long-term improvement in the proportion who see themselves as at least adequately prepared in the use of computers in their classrooms and labs.

One area where there has been a great deal of interest and discussion, but little reliable data, has been the spate of new curriculum reforms developed during recent years, especially the introduction of courses using inquiry-based instructional approaches. Over the years, we have found it difficult to pinpoint how many teachers have fully and formally incorporated these new approaches in their classrooms. In 2005, we

Table 3. Teacher Self-Assessed Level of Preparation in 2005 (2001 results in parenthesis)

	Percent describing themselves as:		
	Very Well Prepared %	**Adequately Prepared %**	**Not Adequately Prepared %**
Basic physics knowledge	66 (72)	32 (27)	2 (2)
Other science knowledge	46 (50)	49 (45)	5 (5)
Application of physics to everyday experiences	47 (48)	46 (46)	7 (6)
Instructional laboratory design and demonstration	36 (39)	50 (46)	14 (15)
Use of computers in physics instruction and labs	25 (24)	43 (39)	32 (37)
Recent developments in physics	13 (15)	51 (50)	36 (35)

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tried a new approach, which made it clear that we wanted to count only those instances where teachers fully implemented the "package" in place of more traditional approaches. Predictably, as shown in **Table 4**, the numbers came down sharply from our looser definitions in prior years. As the table indicates, no single approach had been adopted by more than 6% of the respondents, and only a quarter of all teachers reported implementing any of the eight named programs.

Even if such programs are not formally implemented, the benefits of recent research into how students most effectively learn can find their way into instructional practice and help to improve physics education. Unfortunately, despite more than a dozen years of insightful studies and robust exchanges of ideas within the Physics Education Research (PER) community, only 8% of high school physics teachers report that PER has had an impact on their classroom teaching. Even more discouraging, this percentage had actually fallen slightly from the 10% recorded four years earlier.

On the other hand, a substantially larger fraction of teachers (25%, as opposed to 11% in 2001) say that they have been involved in a collaboration with a college or university that has had a significant impact on their physics teaching. Teacher descriptions of these indicated that many involved individual arrangements with only limited scope, like class visits to a local college or university physics lab, or having a faculty member give a guest lecture in

Table 4. Teacher Use of "Non-Traditional" Approaches to Physics Teaching

	% of Teachers Using
Modeling Instruction Program	6
Physics by Inquiry	6
Active Physics	5
C3P (Comprehensive Conceptual Curriculum for Physics)	3
Interdisciplinary Instruction	3
Real Time Physics	3
Workshop Physics	2
CPU (Constructing Physics Understanding)	1

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their high school class. A number of teachers cited formal programs, usually based in the college, that provided demonstration ideas and materials, in-service training, and even internship opportunities for both teachers and advanced students.

Many long-term physics teachers have commented over the years that one of the most critical factors in their professional development was membership and activity in professional organizations, especially the American Association of Physics Teachers (AAPT) and the National Science Teachers Association (NSTA). This is especially so in physics because, in so many schools, there is only one physics teacher. While the advent of the Internet and the Web have provided vast resources for physically isolated teachers, the lack of intramural colleagues means that professional society membership offers an otherwise rare opportunity for face-to-face professional interaction for many. However, we have found that, over the years, despite the rise in the fraction of physics teachers who have most of their assignment in that subject, the proportion belonging to the two main professional societies has been essentially stagnant for the entire period. More ominously, younger teachers and teachers with fewer years of teaching experience are each less likely to be a member of either AAPT or NSTA.

Moreover, it doesn't appear that teachers are simply deserting the two traditional professional organizations for equivalent alternatives. When we asked whether teachers took part in any other face-to-face forum of science teachers, fewer than 20% said yes. A similar proportion said they belonged to an electronic discussion group or listserv for physics or science instructors, while only 6% reported involvement in any other type of forum for discussing physics education issues. Furthermore, members of the professional societies are more likely to participate in these other activities which are complementary to teaching physics. Thus, those who are not members are further isolated from their peers.

Table 5. Teacher Professional Activities

Percent who reported attending at least once in 2004 a:	All Teachers %	Members of AAPT or NSTA %	Non-Members %
professional association local or national meeting	32	50	17
workshop on physics classroom instruction techniques	36	47	26
workshop on physics lab design or delivery	28	37	20

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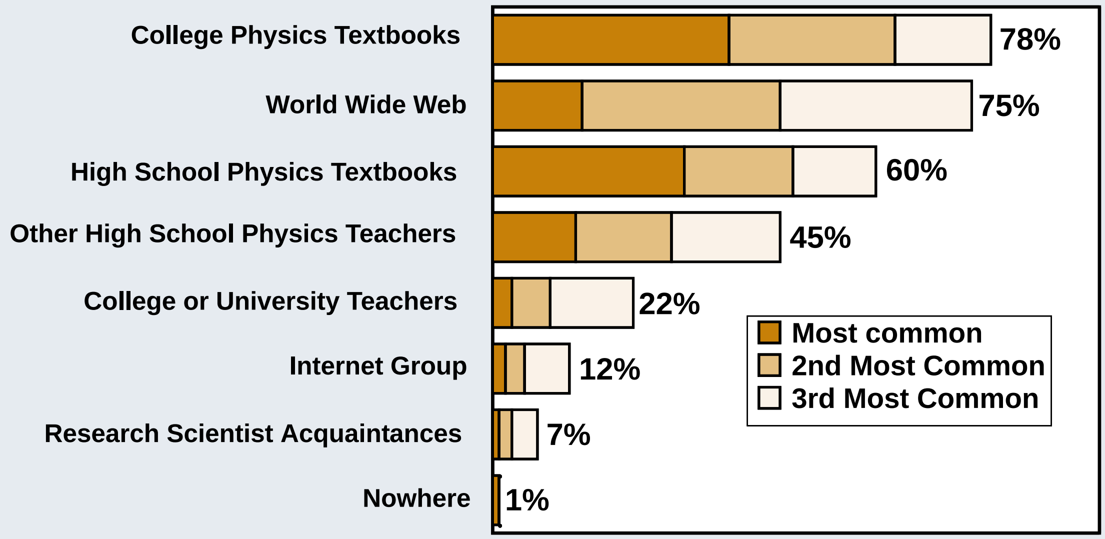
Similarly, as **Table 5** illustrates, only a minority of teachers, whether members of professional associations or not, regularly attend workshops and professional association meetings. Not surprisingly, AAPT and NSTA members were far more likely to be involved in such activities than non-members, but this only serves to underline the extent of professional isolation for those who do not belong to the primary professional societies. Needless to say, professional association membership and professional development activities such as workshops, meetings, and conferences, are important not only for the disciplinary information they may impart, but also for professional and career information, emotional support, and a general sense of community. These are reinforcements which many pre-college teachers, working solo in often stressful circumstances, could find beneficial, but which only a minority seem to use.

Another indication of the professional isolation of many physics teachers can be seen in **Figure 15**. When asked where they turn most often for answers when they have a question about physics content, a large majority selected textbooks as their primary source, and the World Wide Web was commonly listed as a secondary source. The only human resource mentioned with some frequency was other high school physics teachers, and very few mentioned turning to college or university teachers or research scientists that they knew. Finally, when we asked teachers to comment on whether the statement, “I have ample opportunity to share ideas with other physics teachers,” only a third concurred, close to a half disagreed, and another sixth did not feel strongly either way.

Figure 15. Resources Used by Teachers to Find Answers About Physics Content



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V. PROFESSIONAL CHALLENGES

Each time we conduct the survey, we list a set of problems commonly raised at professional meeting sessions, informal discussions, and in teacher comments on prior surveys, and we ask teachers to tell us which ones are currently most serious for them. As **Table 6** shows, the biggest culprits have generally been the same over the years. The problems most frequently rated as serious are insufficient funds for laboratories and equipment, not enough time to prepare labs, and inadequate student preparation in mathematics. It is interesting that problems revolving around labs and equipment have shown some improvement in recent years, especially since, as displayed in **Figure 16**, funding for equipment and supplies has been steadily eroding in inflation-adjusted terms over the past two decades.

We probed teachers in greater detail about the readiness of their students to take physics when they entered the class. As shown in **Table 7**, the areas of greatest weakness were in “thinking scientifically,” using computers, and math preparation. Teachers’ perceptions regarding students’ overall preparation to take physics were relatively stable compared to four years ago.

Table 6. Percent of Physics Teachers Citing Selected Problems as Serious

	%
Insufficient funds for equipment & supplies	31
Not enough time to prepare labs	24
Inadequate student mathematical preparation	24
Inadequate space for lab or lab facilities outmoded	20
Students do not think physics is important	19
Not enough time to plan lessons	18
Difficulties in scheduling classes & labs	12
Insufficient administration support or recognition	10

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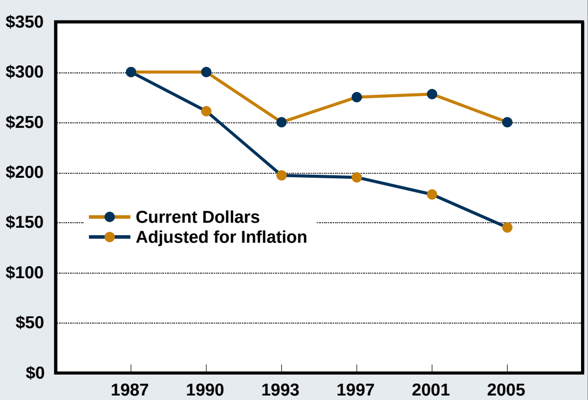
We also asked teachers to tell us their views on key aspects of their work situation and on several currently controversial topics in science education. While some of these were asked in previous surveys, allowing us to gauge any change in teacher opinion over time, others were new, especially questions about the impact of the No Child Left Behind legislation on physics teaching. NCLB had not yet been signed into law at the time of our previous survey, but it has now had enough time for teachers to get a feel for its effect in their classrooms.

Figure 16. Median Funding Available Per Class for Equipment and Supplies: Current and Inflation Adjusted Dollars



AIP Statistical Research Center: 1986-87, 1989-90, 1992-93, 1996-97, 2000-01 & 2004-05 High School Physics Surveys, CPI Data from Bureau of Labor Statistics

As can be seen in **Table 8**, few teachers report much impact, but most of those who do feel that it has been a negative influence. The small impact is not so surprising, when you consider that physics is not one of the subjects for which testing is mandated by the law. Second, most of the physics students whose teachers were covered in the study were juniors and seniors in the Spring of 2005, thus graduating prior to when many of the Act's provisions are set to officially take effect. Finally, many of NCLB's edicts concern the achievement of basic comprehension levels, often at an 8th or 9th grade level, whereas students signing up for

Table 7. Initial Student Readiness to Take Physics: 2005

	Percent of teachers describing their students as:		
	Very well Prepared %	**Adequately Prepared %**	**Inadequately Prepared %**
Math background	16	55	29
Familiarity with general laboratory methods	15	63	22
Use of computers in science	14	54	32
Physical science background	11	68	21
Ability to think and pose questions scientifically	7	54	39

AIP Statistical Research Center: 2004-2005 High School Physics Surveys

Table 8. Teacher Assessment of No Child Left Behind (Public Schools Only)

	No %	**Yes, Positively %**	**Yes, Negatively %**
Have the student testing provisions in NCLB affected your physics classes or curriculum	82	4	14
Have the provisions on teacher qualification in NCLB affected you as a teacher?	84	4	12

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physics tend to be among the academically more advanced at their schools, least at risk for the negative consequences spelled out in the legislation.

More curious is the lack of reported impact of the new teacher qualification rules. Given the long standing shortage of physics teachers, the small fraction of teachers with majors in physics, and the resulting use of "crossover" teachers who are specialists in other disciplines, it is surprising that so few teachers report any problems with these provisions. The explanation lies in the ambiguities built into the rules, and adeptness shown by states and school districts in using these ambiguities to skirt many of the penalties aimed at out-of-field teaching. For example, while it was once thought by many teachers that they would be required to have a college degree in each subject they teach, it turns out that, in most cases, a bachelors degree in almost anything could be made to suffice. The field-specific requirement is that they hold state certification in each subject they teach, and that they can demonstrate their competency, as defined separately by each state, in that subject. And in 2004 the No Child Left Behind rules were further loosened to permit states to continue qualifying science teachers in “broad science.”

So, it turns out that, in physics at least, this is not much of a departure from the status quo. Our earlier surveys had found that essentially every high school physics teachers held at least a bachelors degree. Similarly, 60% said they had full state certification in physics even before NCLB was introduced, and another 24% had certification in general or broad science which included physics. Another 5% more had temporary state certification in physics, with most of these well on the way to acquiring the permanent credential. Almost all the remaining teachers had majors in a science subject such as chemistry, which could potentially qualify them as broad science or physical science teachers and satisfy the NCLB rules in many states. The physics coursework they would have been required to take for that major would presumably allow them to handle any subject-test. In this context, one can see that only a small fraction of teachers who taught physics prior to NCLB were in danger of being barred from continuing to do so.

In addition to their experience with the new NCLB rules, we asked teachers for their opinion about the idea that only people who had majored in physics should be allowed to teach it. We found that teachers were evenly divided on this question, with 43% agreeing, 42% disagreeing, and 15% in the middle. Not surprisingly, teachers with physics and physics education degrees felt far more strongly in agreement, but curiously, almost a third of teachers with no physics degree also concurred.

We also asked for their views on other controversial issues in physics teaching (see **Table 9**). For instance, while we showed results earlier that enrollments in traditional physics had remained stable while enrollments in the course aimed at non-science students had risen rapidly, it is possible that still more students would have signed up for the algebra-trig course if the less-advanced course had not been available. So we asked teachers to indicate whether they felt that enrollments in the latter at their school had come at the expense of the traditional course. Almost half of the teachers expressed no view on it, some perhaps because they felt it was difficult to gauge the trade-off, whereas others, because the conceptual alternative was not offered at their school, probably considered the question not applicable in their case. But of those who did offer an opinion, the view that conceptual physics growth did not come at the expense of regular physics outnumbered the contrary stance by almost four to one.

Table 9. Teacher Views on Career and Policy Issues

	Agree %	Neutral %	Disagree %
All students should take a physics class in high school	80	6	14
If I had it to do over again, I would still choose high school teaching as my career	78	11	11
I prefer teaching physics to teaching other subjects	77	13	10
Only people who majored in physics in college should be allowed to teach it in high school	43	15	42
I have ample opportunity to share ideas with other physics teachers	35	18	47
The sequence of high school sciences should be reversed, so that students take physics first, before chemistry or biology	24	21	55
Conceptual physics enrollments in my school have grown at the expense of algebra / trig physics	11	49	40

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VI. PHYSICS FIRST

Recent years have seen rule changes that influence science course-taking patterns. Over the last fifteen years, almost all states have raised their high school graduation requirements, including the science requirement. During this time, almost all states have shifted from a science requirement of one or two years of high school science to that of two or three years, with a recent shift towards a predominance of three. A report on State Education Policies just released by the Council of Chief State School Officers shows that the number of states requiring at least three years of high school science for graduation rose from 6 in 1992 to 28 in 2006 (Toye, et al, 2007). State requirements set only a floor, and some districts and even individual schools have tacked on an additional year to these minimums. Most schools offer biology, chemistry and physics, and many offer a course in physical science as well, combining chemistry and physics with a smattering of earth science, and usually taken by freshmen and sophomores. Many schools also offer semester-long and full-year courses in earth science or astronomy, as well.

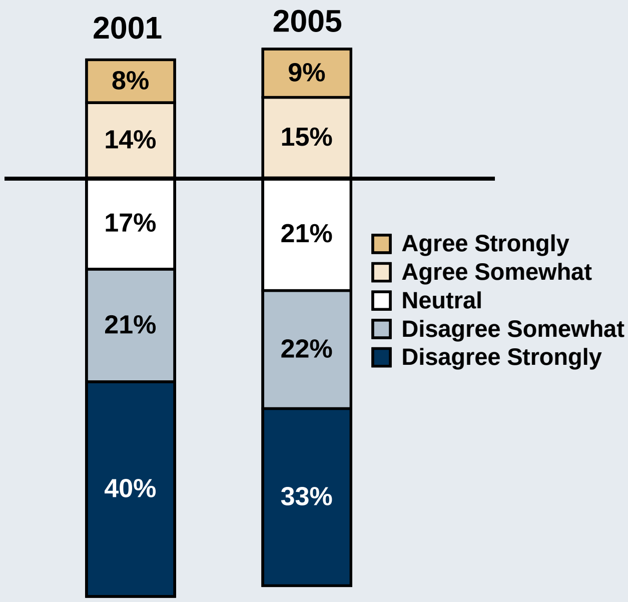
Since biology has typically been the first science course taken in high school, the new standards have resulted in little change in biology enrollments. According to Department of Education statistics, the percentage of high school graduates taking biology hardly moved from 1987 to 2000, rising from 86% to 91%. When we add in the roughly 7% who were counted separately as taking honors biology, it is clear that virtually all high school graduates took biology throughout this period. But, by the same figures, the rising requirements had a strong effect on chemistry, which rose from just under half to around two-thirds in the same period. And, as we have seen earlier using our own figures, the proportional impact was as strong or even stronger in physics, with enrollments rising from 20% of all seniors in 1987 to 33% in 2005.

While there are moves afoot by states such as Texas and New Jersey to require all students, or at least all of those seeking an "academic diploma," to take all three laboratory sciences in high school, we still have a long way to go to get close to 100% in physics. Clearly, even if the current upward trend were to persist, it would take decades to approach 100% unless there were large changes in requirements across the country. Some of those in the physics education community who are impatient with this slow rate of progress have signed on with a pre-existing movement of educators who hold that physics is the foundational science which underpins much of chemistry, which in turn forms the platform for much of what is new and exciting in biology. These scientists and educators have thus proposed to reorder the sequence in which high school science is taught, starting with physics in the 9^{th} grade, and then moving on to teach chemistry and then biology in the subsequent years. Following the "Physics First" course sequence would also create a fast-track for reaching the goal of all high school students taking physics.

The movement to promote the idea and encourage the implementation of Physics First (PF) has been slowly but steadily gaining ground over the last several years. Until now, the only information about the spread of PF was anecdotal, based on teachers that had made themselves known to the formal and informal groups promoting the change. In 2001, we assessed the views of physics teachers about the idea. We combined those views with our data on when students take physics to get a very rough sense of how widespread a phenomenon it was; we identified the upper limit of its spread by the percentage of teachers with a large representation of freshmen and sophomores in their physics classes.

We took another step forward on this issue in 2005 when we asked both principals and teachers directly whether their school had implemented the sequence inversion. Where teachers said yes, we directed them to a module of descriptive and evaluative questions about the change. Our findings

Figure 17. Teacher Opinions on Physics First*, 2001 and 2005



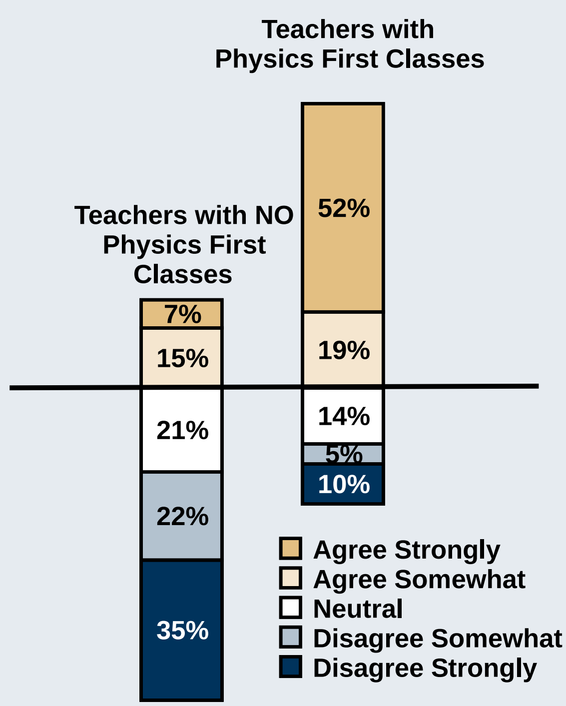
*The sequence of high school sciences should be reversed, so that students take physics first, before chemistry or biology.

AIP Statistical Research Center: 2000-01 & 2004-05 High School Physics Surveys

are presented in the figures and tables in this section. Basically, we found a similar pattern of teacher attitudes regarding PF to what we had found four years earlier (see **Figure 17**). As before, teachers who had implemented PF remained far more favorably disposed to the idea (see **Figure 18**). In addition, these teachers reported themselves well-satisfied with the way the transition had gone.

As **Figure 19** shows, while over three-quarters of the private schools made physics mandatory for all 9th grade students, a little over half of the public schools implementing PF taught physics to only a portion of all entering freshmen. What is more, the practice for these schools diverged widely, falling into three nearly equal categories: 17% of the schools channeled only the most scientifically-advanced freshmen into physics, while 14% did exactly the opposite and offered it only to the least scientifically-advanced, and the remaining 14% made it optional and open to students at all levels. In 2005, we estimate that 4% of all U. S. high schools – 3% of all public schools and 8% of all private schools – had

Figure 18. Teacher Opinions on Physics First*: Currently Teaching and Not Currently Teaching



*The sequence of high school sciences should be reversed, so that students take physics first, before chemistry or biology.

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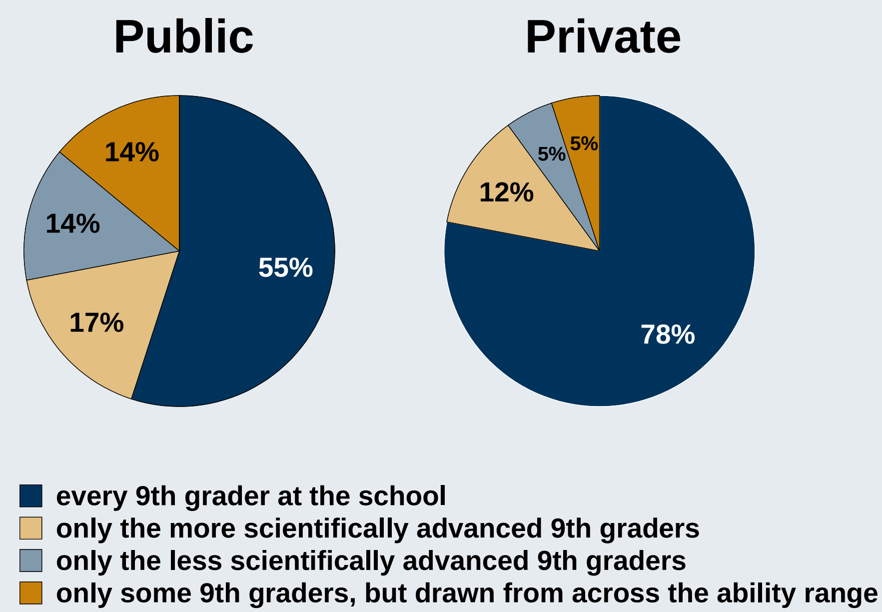
Figure 19. Who Takes Physics First

At Schools Where Physics First is Offered



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implemented some variant of Physics First. Schools with PF tend to be those with larger enrollments resulting in 5% of all students in the nation (4% in public schools and 12% in private schools) enrolled in school with a PF curriculum.

There is no question that PF does have the expected large impact on students taking physics in high school (see **Table 10**). Among public schools where PF has been implemented, 73% of seniors graduate having taken physics; this is more than double the 31% who take physics at non-PF schools. Among private schools, even those that do not offer PF enroll close to 60% of their students in physics by graduation; at PF schools, essentially all students take it.

One of the basic tenets promoted by the originators and early practitioners of PF was the fundamental order of physics first, followed by chemistry, then biology. **Table 11** shows that about half of all PF schools – and more than half of all public PF schools – offer a different sequence. In part, this may be because many states have instituted end-of-course or graduation tests for public high school students, especially since the advent of the No Child Left Behind legislation.

It is not hard to understand why PF was able to take root earlier, and to subsequently spread more widely, in private schools than in public schools. First, private schools are less bureaucratic and teachers are more able to experiment with new pedagogical approaches. Public schools are often part of larger districts with internal and external authorities that have a legal right and responsibility to oversee and/or participate in any major curricular change. Second, private schools are also generally smaller which enhances flexibility. Finally, private schools, especially the secular private academies where PF has spread the farthest, have a school- and self-selected student body – one that is on average more economically advantaged, more academically oriented, and more often college bound than the typical student body at a public school. These students (and their parents) are more likely to feel comfortable with a requirement to take physics (viewed as an academically-prestigious course) and to take it earlier. In addition, these schools are more likely to have and be willing to commit the substantial resources necessary to adapt lab facilities, buy books, fund teacher training, and provide all the ancillary support required to help a new program succeed. In this environment, enthusiastic private school teachers who undertake the development and introduction of a PF curriculum probably get stronger backing from their administration, from other teachers, from parents, and from students.

Table 10. Percentage of Students Who Take Physics at Physics First and Non-Physics First Schools

	Public %	Private %
Physics First taught at school	73	100
Physics First not taught at school	31	57

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Table 11. Sequence of Science Courses at Physics First Schools

	Public %	Private %
Physics, followed by chemistry, then biology	37	57
Physics, followed by biology, then chemistry	50	35
Other Sequence	13	8

AIP Statistical Research Center: 2004-05 High School Physics Survey

It is not at all surprising that PF has been far slower to spread in public schools, Furthermore, where it has taken root within that sector, PF has been more successful in more economically-advantaged suburban schools. The greatest challenges to successful implementation are present in the many, large, hard-pressed urban districts, as well as in the thousands of small resource-poor districts scattered across the rural sections of our country.

The situation in public schools, especially in large urban districts, is likely to be quite different. While individual public school physics teachers may be very excited by and favorable to the change, large-scale curricular decisions are generally made by the district as a whole, and then passed down to individual schools and teachers. Students and parents are likely to be frightened of physics' reputation as a difficult subject, appropriate only for the "best" students. Principals and other teachers may be wary of ambitious mandates with little real funding and mindful of previous reforms that not only cost human energy and scarce resources but also turned out to be educational fads that lasted only a few years and were then abandoned for the next new thing.

In San Diego, a pioneer among urban districts in adopting PF, an enlightened and committed administration devoted prodigious planning, thousands of staff hours and millions of dollars to implement the new program properly; however, the obstacles ultimately proved overwhelming. Within a few years, parental and student opposition and teacher resentment and misgivings at what they perceived as top-down decision making torpedoed the new program and caused the school board to make it optional, resulting in a reversion to the previous system in many San Diego schools.

Some supporters of PF have suggested that a major obstacle in implementation is the teachers themselves. Currently, the students with whom the high school physics teachers work tend to be among the most academically adept at the school, who have enrolled voluntarily in what is typically seen as a challenging course. It has been suggested that physics teachers may be leery of PF because they would be teaching students who are younger, represent a broader diversity in academic abilities, and who are perhaps forced to take a course many fear and/or see as irrelevant.

While this observation is undoubtedly true in some cases, it may not be quite as central as often argued. Around 80% of physics teachers believe that all students should take a physics class in high school. While this does not address the presumed objection about the age of the students, it does suggest that most teachers believe that physics should be available to all students – across the academic spectrum.

Thus, the vast majority of growth in physics enrollments reflects a diversity in academic abilities. In the long run, as we will discuss in Section VII, the biggest and most important challenge will be to reach those students who are heading for two-year colleges or into the workforce after graduation, and conceptual physics and inquiry-based approaches can play a big role here.

PF and a Second Year of Physics

Another argument often offered in favor of PF is that it would encourage more students to take a second year of advanced physics before they graduate high school. Since we focus on teachers and not students, we are not able to distinguish between first- and second-year physics taking for individual students. We did look at the overall rate at which students took advanced physics classes (defined as either variant of the Advanced Placement course or non-AP 2nd-year physics), and we found a mixed picture. Most directly, we found no evidence that physics students were more likely to enroll in advanced courses at PF schools.

In both PF and non-PF schools alike, around one in ten physics students took an advanced course. Since proportion of students taking physics is larger at PF schools, the overall percentage of the student body who took advanced physics is also larger: 5% in PF schools versus 3% elsewhere. Even so, the percentage remains very small regardless of whether PF is implemented or not. Perhaps this should not be surprising given that, especially in public schools, many of the extra students brought in by PF are probably among the least likely (based on prior demographic and academic factors) to take advanced physics in high schools.

The Outlook for Physics First

So what is the most likely future of the Physics First movement? PF will probably continue to spread steadily among private schools, as well as among public schools in the wealthier suburbs of metropolitan areas. The growth will likely be much more modest in large urban districts and in most rural areas. Impediments to PF growth in these areas include the continuing shortage of qualified teachers, the unwillingness or inability of districts and administrators to spend what it would take to implement PF properly, problems aligning PF with NCLB-inspired state standards and testing, and the trepidation of parents, teachers and students about physics.

The issue of winning over current physics teachers, the majority of whom remain opposed to the idea, is especially crucial in these districts. These teachers would have to play a key role in implementing the change, adapting new textbooks and existing classroom and lab space and equipment, and, most important of all, mentoring and supporting teachers new to physics as they face the challenge of teaching unfamiliar material. If the current physics teachers are enlisted and sufficient resources are brought to bear, the transition has the potential to go smoothly and to be beneficial for all involved. However, if these ingredients are missing or inadequate, this will become a recipe for potential disaster.

Even without PF, students seem to be taking physics earlier in their high school careers. Much of the current growth has been among students taking it in their junior year, rather than in the more traditional senior year. This behavior has resulted from both rising science-taking requirements and increased college competition that prompt many students to start the traditional laboratory science earlier. Significantly, this pattern has been most pronounced among those states with the highest physics enrollments; in these states, enrollments are close to, or have already, surpassed the 50% enrollment mark for physics. As states continue to strengthen their science requirements, it is likely that this will become more typical – with, or without, Physics First.

VII. TEACHER SATISFACTION, RETENTION AND TURNOVER

As concerns about the United States' current or impending "educational crisis" have risen in recent years, one of the areas of greatest unease has been the adequacy of the supply of pre-college teachers, and especially science and mathematics teachers. Some have expressed fears about the aging of the teacher corps and an imminent wave of retirements, high and growing rates of attrition among both early- and mid-career teachers due to poor pay and working conditions and the availability of attractive alternative careers, and a low and falling number of new teachers coming through the training pipeline.

In previous rounds of our own study, we have indeed found repeated indications of shortages of well-qualified high school physics teachers, including descriptions by school principals of the difficulty in replacing teachers who retire or leave. Broader studies that have documented general shortages of high school science and mathematics teachers often identify physics as the academic field with the greatest proportional shortage of teachers (AAEF, 2005). The demands of rising enrollments have only heightened the focus on the supply of teachers, and on patterns of teacher retention, turnover, and recruitment.

Our current survey, while only able to address the situation in physics, contains questions that were included to shed light on each of these areas of concern.

One key to teacher retention is career satisfaction among teachers, including their feelings about teaching specific subjects. This is a critical concern in a discipline like physics, where the vast majority of teachers have had their primary formal training in another field, and for whom physics may be only a secondary or even tertiary assignment. Here we find fairly encouraging news. As can be seen in **Table 12**, almost 80% of the teachers, including more than two-thirds (68%) who were trained in other fields, expressed a preference for teaching physics over any other subject. And when we turn to overall satisfaction with their choice of teaching as a career, we find that only about two physics teachers in 10 felt that they wished they had chosen a different career. These are extraordinarily strong numbers, and suggest a level of comfort with their career that bodes well for physics teacher retention. Similarly, when teachers are queried about future plans, which could be impacted by external factors such as family demands and long-term plans for further education or training, as well as dissatisfaction with their current situation or a desire for new challenges, 84% of physics teachers from across the range of career stages anticipate remaining in high school teaching right up until retirement.

Turning to the seniority distribution of teachers and its implications for future retirements, we find that here, too, the numbers are relatively encouraging. As far as the impact on retirements is concerned, the "age profile" of physics teachers has never been healthier during the time we have been conducting this survey. In terms

Table 12. Teacher Opinions of Physics by Type of Degree

	Physics Major or Minor (includes education) %	No Physics Degree %
I prefer teaching physics to teaching other subjects.	89	68
If I had to do over again, I would still choose high school teaching as my career.	79	76
Percent who plan to remain in high school education until retirement	84	84

AIP Statistical Research Center: 2004-05 High School Physics Survey

Table 13. Teaching Background in Selected Survey Years

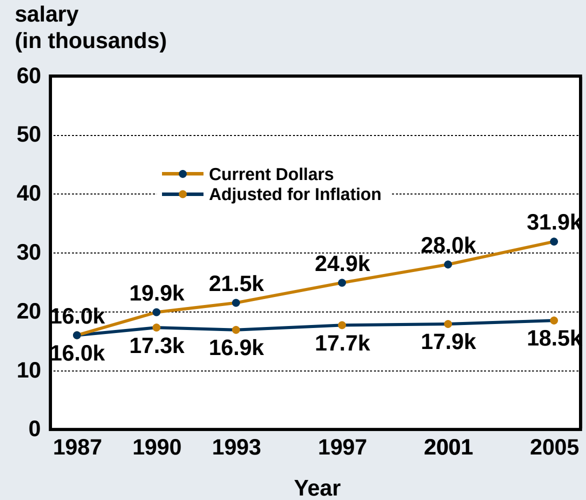
	2005	2001	1993	1987
Median years teaching physics	8	7	11	8
Years teaching secondary school (%)				
1-5	25	25	19	18
6-10	21	20	17	15
11-20	27	25	27	40
21+	27	30	37	27
Type of school (%)				
Public	79	81	81	82
Private- Secular	6	5	5	6
Private- “Mainstream” Religious	10	9	10	9
Private- Fundamentalist	5	5	4	3

AIP Statistical Research Center: 1986-87, 1992-93, 2000-01 & 2004-05 High School Physics Surveys

of years of high school teaching experience, as **Table 13** shows, the last time the fraction of teachers who had more than two decades’ seniority was this small was in 1987, our first survey year. Turning to the other end of the seniority spectrum, we found a higher percentage (46%) of teachers still within their first decade of teaching than we have in any of the previous surveys. On the other hand, as we noted in the 2001 report, the median age of physics teachers had been slowly but steadily climbing, and the latest results show it stabilizing at a relatively high level. The explanation for these two seemingly contradictory findings probably lies in the pattern, treated below in greater detail, of a surprisingly large proportion of teachers who come to teaching not directly out of college, but rather after trying another career.

One factor which may not contribute much to retention is salary. The overall median salary for physics teachers in the survey was $43,000 per year. The 14% increase in median starting salary from 2001 for new teachers compares favorably to the 10% growth in prices overall (see **Figure 20**).

Figure 20. Starting Salaries for New Teachers: Current and Inflation-Adjusted Dollars



AIP Statistical Research Center:1986-87,1989-90, 1992-93, 1996-97, 2000-01 & 2004-05 High School Physics Surveys
CPI Data From Bureau of Labor Statistics

However, salaries earned by new physics bachelors degree recipients who go into non-academic physics-related jobs are higher than those for new teachers (Mulvey, 2006).

There is a good deal of uncertainty in many discussions about teacher turnover. This lack of clarity stems, in part, from the fractionalized academic system that leads to inconsistencies in data collection methods and from the fact that teachers themselves are not always sure of their future plans. Trying to avoid this latter uncertainty by waiting to query teachers until after separation brings up another obstacle, the difficulty of tracking down and getting responses from those who have left a system.

Our survey tried to address the turnover questions from both sides, asking current teachers about plans for leaving, and comparing this to the inflow of new teachers. Our real subject of interest is actually not the gross frequency of coming and going from schools, which includes lateral transfers that do not impact the overall supply of and demand for physics teachers, but rather the true rate of attrition *from the profession.* To gauge this, we need to factor out teachers who simply switch schools without an interruption in their physics teaching. At the same time, we also need to filter out the fairly frequent comings and goings of those teachers who temporarily switch out of physics in a given year but remain on staff at their school. Clearly, trying to gauge true rate of teacher turnover at this level is no easy task. The fact that we are focusing on a single discipline, and moreover a small one, in which teachers often teach only part-time or occasionally, makes it that much more of a challenge.

In the 2005 initial survey of principals to ascertain whether sample schools taught physics and to obtain teacher names, we found that 8% of the teachers who taught physics four years earlier were still at the school but not teaching physics that year (although we had no information on whether they had done so between surveys). Fifteen years earlier, when physics enrollments were lower, the figure was 14%. A different measure of the same pattern came on this round's teacher survey, where almost 60% of teachers provided figures that showed them having taken a break of a year or more from physics during their teaching career, and 23% had taught it in no more than half of the years since they began teaching. Indeed, at some smaller schools which offer physics and chemistry in alternate years, this is an unavoidable by-product of the course rotation. Still, in terms of the implications for physics teacher supply and demand, we have no reason to think that all this movement in and out of physics teaching is not roughly in balance, and thus neutral in its impact. We need to count only those who are leaving the teaching profession entirely, due either to retirement or to switching careers. It is only these teachers who are truly "turning over", and as a result generating demand for new entrants to high school teaching as replacements.

When we asked current teachers what their plans for the immediate future were, 4% of the respondents indicated that this was their last year of high school teaching. This is similar to the figure from earlier surveys, although they may all share some response bias, since teachers planning to leave the profession who are contacted towards the end of their final year may be somewhat less likely to respond to the survey. As a check on this, when we look at the number who project that they will be leaving over the next subsequent five years, we get 27%, which averages out to somewhat over 5% per year. Of course, this figure may also have problems, like the accuracy of asking respondents to anticipate actions farther in the future, but it may still offer some improvement over the first number. Clearly, our responses can only serve to provide a rough estimate, but let us assume for simplicity sake that the true number lies somewhere around 4% to 5% of the total of 23,000 teachers. If this range is relatively stable from year to year in the short term, as it has been over the two decades that we have conducted the survey, we can have some confidence in an estimate that somewhere around 1,000 physics teachers per year leave teaching, either retiring or choosing another career.

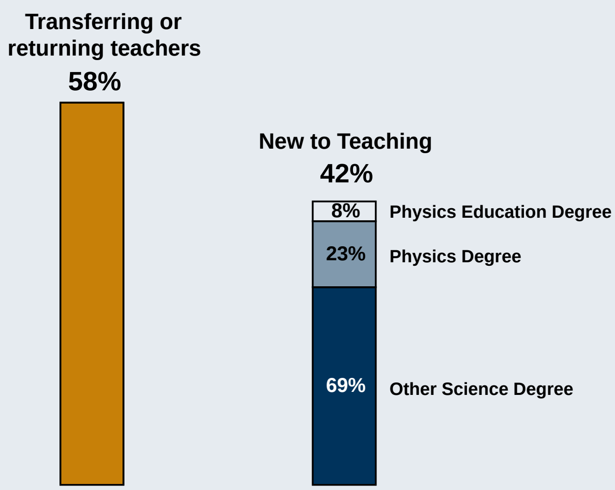
In a steady state system, the number of teachers leaving would equal the number arriving. However, we know from our surveys of principals that the current physics teacher system is not quite steady-state, with physics teacher numbers slowly increasing over the years, growing an average of just over 1% a year over the past two decades, and rising at about twice that rate during the past four years. When we ask our teacher-respondents about the number of years' experience they have in high school teaching, about 5%, representing roughly 1,150 teachers, say that they are in their first year of teaching. This number, too, may be understated somewhat by teachers who include their student teaching time in their response. Support for this supposition comes from the fact that, despite the well-documented pattern of higher attrition among teachers in their first couple of years, we have consistently found slightly more teachers indicating that they are in their third or fourth year of teaching than reporting that they are in year one or two. Taking this altogether, and bearing in mind the abovementioned caveats, it does appear that the overall turnover rate has hovered somewhere between 4% and 5%, and that, adding in the growth in the teacher corps, there is currently a need for somewhere around 1,200 new physics teachers each year.

Another uncertainty is that an unusual jump in teacher demand may, in the short term at least, not necessarily generate an equal rise in the demand for brand new teacher recruits in physics. Rather, some of the need may be met by asking other science teachers already on staff, both those with some prior physics experience and even those without, to add a class or two of physics to their assignment. The presence of this “reserve corps” of potential physics teachers may add some flexibility to the supply situation, but, just like the strategy of asking physics teachers to teach more physics in response to rising enrollments, it has built-in limits and is impossible to sustain as a long-term solution to supply problems. These factors all add further to the difficulty of attaining precision in figuring supply and demand numbers, but do not change the thrust of the main determinants that point to an underlying turnover in the overall ranks of physics teachers in the range of around 5%, currently a bit over 1,000 teachers, each year.

From our survey, we know something about the new teachers. In terms of factors like gender, minority group membership and the number of physics classes assigned, the new teachers largely resemble their more experienced counterparts, and there is thus little sign of significant upcoming change, although that is also affected by patterns of attrition as well as entrance. But examining the characteristics of new teachers did reveal one interesting pattern which had not been previously apparent and may not be widely recognized. Based on respondents' reports of the year in which they earned their bachelors (and, if applicable, masters) degree, and roughly corroborated by their reported age, it turns out that fewer than half of the new teachers come straight out of college, either with a bachelors degree or after having matriculated directly into a graduate education program and then come out with a graduate degree. Most appear to have emerged from school and first tried something else for anywhere from one to many years before deciding to opt for high school teaching. For these “delayed” first-year teachers, the median age seemed to be around thirty, suggesting a substantial period of work in another environment before coming to high school teaching, although some of the intervening years could also have been spent in study or out of the workforce for other reasons.

Regardless whether new physics teachers have come straight from college or have tried some non-teaching option first, one major concern within the physics community is their academic preparation in physics. The most commonly sought measure of this is the percentage of new physics teachers who have physics degrees. From our survey, our estimate is that the current percentage for new teachers is around 24% (~270) with physics bachelors degrees and another 8% (~90) with physics education degrees, and the balance almost universally with science, mathematics, or science/math education degrees. Perhaps even more important is the physics preparation of the other two-thirds. Counter to fears that some new teachers are being placed in classrooms with virtually no physics preparation at all, we found that for teachers in the first three years of their career, even those without physics degrees had a median of three undergraduate physics courses, and only 3% did not have any college physics credits (see **Figure 21**).

Figure 21. Background of New Teacher Hires in Physics



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In virtually all other respects, there were no or only minor differences in the background and teaching situation of recent recruits and more experienced teachers. Despite reports that new teachers are often assigned to the worst schools, we found that, in physics at least, there was no significant difference in the representation of new versus old teachers at the two ends of the socioeconomic spectrum. Nor, despite the excitement about new instructional approaches, was there any more familiarity with Physics Education Research (PER) or use of non-traditional approaches among newer teachers. Slight differences were found in only a few places. First, more new teachers, especially those in public schools, felt a bit less well-prepared in laboratory design and demonstration techniques. Additionally, slightly fewer were members of the American Association of Physics Teachers, a prime forum for practical tips on classroom presentations and lab activities.

Survey responses also provide us with a rough estimate of the prevalence of transfer among physics teachers, whether the latter are moving directly from one school to another, or have taken time off from teaching in between. While 12% of respondents, or about 2,750 teachers, reported that they were new to their school during the survey year, when we remove the approximately 1,150 who were new to teaching, this leaves us with around 1,600 experienced teachers, 7% of the entire physics teacher corps, who had transferred in, mostly just prior to the survey year. Clearly, this represents a considerable amount of coming and going among teachers. Based on our earlier follow-up study of leavers, we estimate that roughly two-thirds of these teachers are transferring directly from one school to another, while the remainder are coming back to physics teaching after leaving their previous school and either taking time off (typically for family reasons, illness or, occasionally, a sabbatical) or trying their hand at something other than high school teaching.

In many recent studies forecasting teacher shortages across the board in the next decade or so, one of the major concerns was the reportedly high rate of attrition among in-service teachers, especially those in the first years of their career. There may be room for some skepticism about the level of the overall figures usually cited, but in physics, at least, our numbers suggest a similar pattern but at a somewhat less dire level.

The greatest projected attrition, as can be seen by **Table 14**, is indeed in the first three years of teaching, where about a third of teachers say that they think they will switch careers at some point prior to retirement (generally 25 to 30 years away), and 7% indicate that they plan to leave after the current year. These numbers are especially high for teachers at private school, and somewhat lower among public school teachers. For those past three years but still in their first decade of teaching, about 20% say they plan to switch before retirement, and that number falls to 12% for those in their second decade of teaching, 6% for those in their third decade, and only 2% among those beyond that. Essentially, the first years are a period of adjustment and evaluation of career choice. Those remaining are likely to grow more comfortable with the role over time. As the years pass and they begin to build up credit in the civil-service-style retirement systems, teachers become far less likely to switch to another career. Thus, the percentage of those reporting plans to leave teaching at the end of the current year also falls off quickly, dropping from 7% for those in the first 3 years to 3% for those with 4 to 5 years experience, and then to 2% for teachers with 6 to 20 years seniority. It is only past the 20-year milestone that the number rises dramatically, to an average of 8%, as actual retirements start to kick in.

The different patterns among public and private school teachers reflect in large part the impact of contractual agreements between public sector teachers' unions and local school boards. Low salaries help contribute to a private school turnover among teachers in their first three years – an average of 12% per year – that is more than double the 5% figure for new public school teachers. But then figures in both sectors

Table 14. Retirement and Future Plans by Years of Teaching

	Years Teaching High School			
	1 to 3	**4 to 10**	**11 to 20**	**21+**
How many more years do you expect to teach high school? (%)				
This is my last year	7	2	2	8
1 to 5 years	22	17	17	49
6 to 10 years	14	18	22	29
11 to 19 years	13	20	41	12
20 or more years	44	43	18	2
% indicating plans to remain in high school teaching until retirement	67	79	88	96
% hoping to change careers before retirement	33	21	12	4

AIP Statistical Research Center: 1986-87, 1992-93, 2000-01 & 2004-05 High School Physics Surveys drop rapidly and even out to a turnover rate of about 2% per year, a rate that holds steady for most of their careers. After two decades, the public figure starts to rise again as retirements kick in, doubling among teachers 20-29 years out to an average of 4% leaving each year, and then rising to an average of about 15% per year for those with 30 or more years seniority. But among private school teachers, with few contractual agreements like "25 or 30 and out" and less generous pensions, the pattern is far more attenuated. In fact, the turnover rate for teachers in the 20-29 year seniority category falls to the lowest of all, an average of only 1.6% per year, while in the 30+ group it reaches only 7% per year, stretching out retirements to far older ages than for public school teachers.

But, all in all, the pattern for teachers is not that different than for many of those following other career paths. In the early stages, there is considerable movement in and out of given occupations, as new graduates try out options and find the one that satisfies them best. After a few years, most young workers settle down in a particular choice and stay there for the balance of their worklife. As we noted earlier, this pattern is especially noticeable among public school teachers, where a relatively-generous retirement system is a major attraction. In terms of turnover, to the extent that physics teachers can be helped to persevere through the difficulties of the early years, attrition would recede as a major contributor to the endemic shortage that we have seen.

VIII. REACHING THE CRITICAL MASS

Stepping back to take in the "big picture" of all these findings in the context of the larger United States education system is often a challenge, in part because the data describing that larger system are themselves often hard to nail down. Much of our knowledge of our nation's overall system derives from figures gathered by the 50 states and 15,000 local school districts that actually administer the schools and collect the data we use. While great efforts are made to promote homogeneity, there are indications that methods, definitions, and classification systems may vary, at times significantly. Another place where different methodologies also cause problems are the persistent and sometimes considerable discrepancies in the figures reported by various government agencies. For example, the number of U.S. high school graduates as reported by the Department of Education using data aggregated from the states differs from the number collected by the Department of the Census based on the

Current Population Survey. In our study, when we need to describe the broader context, we generally rely where possible on Department of Education data, as they are collected ultimately from sources – the schools – more akin to our own, and produce results more in line with what we are independently finding in our own surveys of schools and teachers. But the discrepancies serve as a warning that these numbers need to be treated with caution.

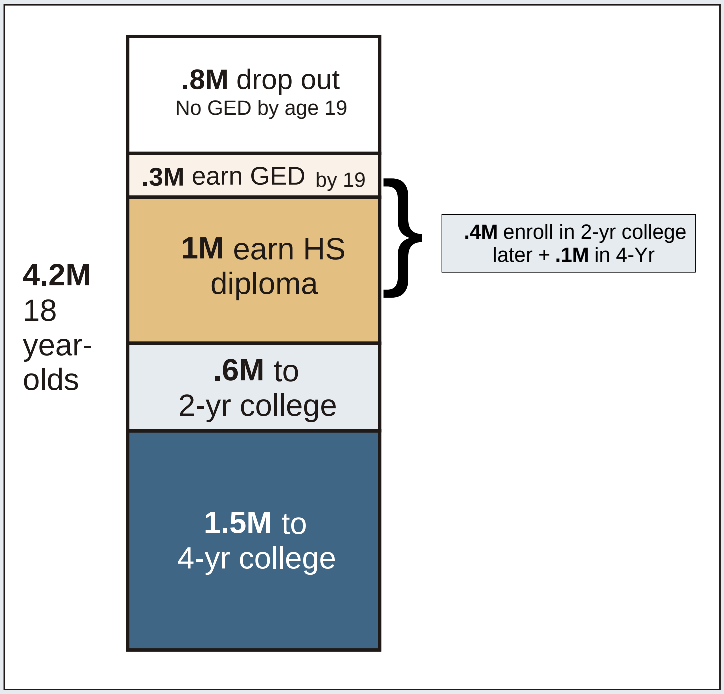
Using Department of Education figures, as reported in the 2006 Digest of Education Statistics, **Figure 22** illustrates the next step for students as they emerge from our secondary education system, with some pursuing higher education and further training and others directly entering the labor force as full-fledged adult members. Ultimately, about three out of four US citizens earn a regular high school diploma (with half the remainder ultimately earning a General Education Diploma (GED) or equivalent credential), and a slowly rising proportion of the regular graduates, now approaching two-thirds, matriculate into college, including two- and four-year colleges, either directly or within a year, with another few percent entering college after a longer delay.

Our system is unusual compared to those of most other nations in the world in two major respects. First, many countries begin tracking their students after primary school or in the early secondary grades, directing students into different types of schools leading to different types of credentials, whereas our system, at least nominally, directs the vast majority of students into similarly-labeled high schools to pursue a homogeneous credential, the high school diploma. Second, while the typical age of graduation varies by a year or two in different national systems, the roughly two-thirds of secondary graduates that our system sends on to the tertiary level is at the high end of the global scale, representing a bit more than half of the overall age cohort.

But despite the appearance of a more equitable outcome, our system is actually quite stratified in ways similar to other developed nations. Here, as elsewhere, those going on to college, especially four-year programs, are clearly separated from the rest, with different academic, social and curricular experiences, and physics is one of the courses that often act as a marker for that differentiation. A high school course in physics is increasingly seen as a useful and even necessary credential for any student heading to a four-year college or university. Yet, on the other side of the academic divide, among students heading for two-year schools or directly into the workforce, the presence of physics on a high school transcript is still uncommon.

In terms of the numbers, this difference plays out in two ways. Within each high school, those on the academic track and bound for four-year college programs are much more likely to have taken the math and science courses that are typically treated

Figure 22. Immediate High School Outcomes for Students in 2005



USDOE -NCES: *Digest of Education Statistics & Projections of Education Statistics to 2014*,
American Council on Education: *The American Freshman, 2005*

as precursors to taking physics in their early high school years, making it more likely that they would sign up for physics as an elective. Unfortunately, since we do not survey students, and teachers cannot be reasonably expected to have an accurate picture of the aspirations of students both in their classes and not in their classes, our survey can't shed much light on this within-school sorting.

However, because schools generally draw students from defined geographical catchment areas, and since neighborhoods tend to be defined in part by economic variables such as housing prices, there is, in addition to the within-school sorting just described, considerable socioeconomic variation of student bodies in the aggregate from school to school. Attendance at four-year colleges and universities is still highly correlated with socioeconomic background in this country (Planty, et al 2007), and physics is typically seen as one of the "college-prep" courses. So, it is not surprising that we find variation from school to school in the breadth of the physics program and in the proportion of students enrolled, depending on the overall socioeconomic characteristics of the schools being compared. These differences are illustrated in the tables and figures on the following pages. While we need to remember that such an analysis reveals only a part of the differences by academic orientation (missing the within-school component discussed above), the patterns they show are still strong enough to illustrate the place physics occupies in the curricular pantheon.

While there were several existing measures we could have used to gauge the relative aggregate socioeconomic profile of a school's student body, most of them had clear disadvantages. Using an external indicator such as a school's zip code or census tract to define location, and then ranking locations according to some associated socioeconomic variable such as median household income or percent of residents with college degrees is problematic because school catchment areas do not coincide, normally not even approximately, with such predefined boundaries. The commonly-used percentage of students qualifying for free lunches works fine to distinguish schools at the low end of the economic spectrum, but is a poor indicator for those at the higher end. Even asking students directly about their parents' income has been found to be a poor measure, because many students simply don't have an accurate idea of the correct number, or have feelings about reporting it accurately even if they do. Income measures generally also run into problems with regional and local variations in living costs and purchasing power, which are difficult to correct for.

Given these problems, we opted for simply asking teachers to rank their school on a five-category scale that compared the economic circumstances of their student body to what they viewed as the average for their metropolitan area (or county, in rural sections). While this is only a rough measure, the five point scale is relatively easy to conceptualize, and we have found that there is considerable agreement between principals and teachers, and among multiple physics teachers where applicable, on the placement of their school on this scale. Of course, this works only for public schools, since private schools have, almost by definition, a self-selected and school-selected student body that is heavily weighted towards the upper end of the socioeconomic scale.

When we compare public schools using physics teachers' assessments of the relative economic standing of their student bodies, we find some strong contrasts in physics enrollments and programs and teacher background and situations, and some places where socioeconomic factors make almost no difference. As **Table 15** shows, some of the latter include areas where differences are frequently assumed to exist. Thus, while it is often believed that the teachers in poorer schools are younger, have less teaching experience, and are less well-established in their school, we found no statistically-significant discrepancies in this regard among teachers with physics classes.

On the other hand, when it came specifically to physics background and experience, Table 15 shows significant differences on a number of dimensions. For example, despite the lack of difference in overall teaching experience, physics teachers in the poorest schools have fewer years' experience specifically teaching physics, with almost half having taught physics for five years or fewer in their careers. This may in part be a natural result of smaller physics enrollments and thus opportunities to teach in the wealthiest schools, nine physics teachers out of ten have at least two physics classes, whereas in schools at the middle or lower rungs of the socioeconomic ladder, half of all physics teachers have but one class in the subject. But another source of the differential in physics experience is likely to be the situation engendered by the extreme shortage of physics teachers nationwide, which likely permits the most experienced and best prepared to choose more desirable assignments. Thus, the Table also shows that almost half of the physics teachers in the richest schools held a degree in physics or physics education, while only a quarter did so in the poorest schools. And thus not surprisingly, far fewer physics teachers at poorer schools could be classified as specialists in the field,

Table 15. Characteristics of Physics Program and Teachers by Socioeconomic Profile of School* (Public Schools Only)

	Much better off than average	Somewhat better off than average	Average	Somewhat worse off than average	Much worse than average
Median years teaching high school	13	12	13	11	10
Median years teaching physics	10	9	8	7	6
Median age	44	45	45	47	46
Median number of physics classes	3	3	2	2	1
% with physics or physics education degree	45	37	31	28	24
% who are specialists based on background factors	45	37	29	26	21
% who describe themselves as specialists	79	65	51	49	47

*Teacher/principal assessment of student economic circumstances relative to other schools in local area.

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regardless of whether we used background variables or asked the teachers themselves.

Needless to say, compounding their generally more limited backgrounds in physics, the conditions that physics teachers confront in the poorer schools, and the level of resources and support they are given, are far more challenging than what is available to their colleagues in more favorable circumstances. Over half of the teachers in the poorest schools complain that their incoming students have inadequate math skills to handle the work, compared to only about one in eight of the teachers at the best-off schools (see **Table 16**). Similar, if not quite as sharp, differences emerged on every single dimension of student preparation that we asked about. **Table 17** reveals that the same type of discrepancy emerged when we asked about what were the serious problems the teachers faced. The poorer the school, the more widespread were the problems, with the gap being quite substantial on some dimensions, such as lab space and funding, student attitudes about physics, and the previously mentioned student math preparation. Small wonder then that physics teachers at poorer schools were less likely to prize physics teaching over other subjects. Sadly, they were also less than half as likely to be active in AAPT, described by many teacher-members a key

Table 16. Student Preparation by Socioeconomic Profile of School*: Inadequacies in Preparation (Public Schools Only)

	Much better off than average %	Somewhat better off than average %	Average %	Somewhat worse off than average %	Much worse than average %
Math Background	13	23	30	42	52
Physical Science background	15	16	20	29	36
Ability to think and pose questions scientifically	32	41	39	46	56
Familiarity with general laboratory methods	17	17	21	25	35
Use of computers in science	22	30	34	38	44
Reporting a decline in overall preparation	20	19	22	25	30

*Teacher/principal assessment of student economic circumstances relative to other schools in local area.

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venue for gaining emotional support and useful professional knowledge.

The differences just described serve to underline the big challenge facing high school physics education in the coming years. On the one hand, as discussed above, the recent enrollment gains in physics have been accompanied by a significant broadening of the curriculum, creating a positive feedback loop. Data from the Department of Education's newest longitudinal study, following current students as they work their way through the education system, has not yet as of this writing reached the point where we can look at enrollment by post-secondary outcomes.

But even relying on data from the previous study, now more than a dozen years old and

Table 17. Problems Affecting Physics Teaching by Socioeconomic Profile of School*: Proportion of Teachers Rating Issues as a Serious Problem (Public Schools Only)

	Much better off than average %	Somewhat better off than average %	Average %	Somewhat worse off than average %	Much worse than average %
Insufficient administration support or recognition	8	8	10	13	15
Difficulties in scheduling classes and labs	8	11	12	14	22
Inadequate space for lab or lab facilities outmoded	11	16	20	24	39
Students do not think physics is important	12	13	20	25	42
Inadequate student mathematical preparation	13	20	22	35	51
Not enough time to plan lessons	16	15	18	25	26
Insufficient funds for equipment and supplies	20	26	36	41	51
Not enough time to prepare labs	21	22	22	32	39

*Teacher/principal assessment of student economic circumstances relative to other schools in local area.

AIP Statistical Research Center: 2004-05 High School Physics Survey

taken in the early portion of the recent increases in physics enrollment climb, 40% of the students heading for four-year colleges and universities took physics. Given the double-digit increase in the overall percentage taking physics since then, it is almost certain that the new figures will show at least a majority of this group now take at least one physics course in high school.

Thus, looking ahead, it seems likely, as we noted earlier, that the proportion of high school students bound towards four year colleges and universities after graduation – and who take physics in high school – will continue to grow steadily in the future. Moreover, this trend may be boosted still further in coming years if physics becomes a formal requirement for entrance into all, or at least a subset, of four-year campuses in an increasing number of states, although so far such a requirement is still in the whispering stages.

Soon, however, this growth in physics enrollment must slow down. Indeed, much of the potential for this type of growth has almost certainly already been realized. Meanwhile, very little growth in physics-taking has taken place in the other half of those earning high school diplomas, those heading for two-year colleges or directly out into the workforce after graduation (to say nothing of those who drop out at some point prior to graduation, among whom physics taking is virtually nil). For physics instruction to break through its historical confines and spread into this population, an even greater shift in disciplinary culture and instructional approach is likely to be required. Physics educators will face a need to recast the material they present and the manner in which they present it, to meet the background and the interests of the new population. Major changes may be necessary in physics' placement in the high school curriculum. Most importantly, all these changes will need to be coordinated with each other, to enable the disparate components of the physics education engine to work in harmony to produce the desired outcome, a population that is cognizant of, comfortable with and still curious about the principles of physics and scientific inquiry.

APPENDIX A. ADDITIONAL TABLES OF FINDINGS

Table A-1. General Characteristics: Physics Programs

	Percentage of all schools	Percentage of all enrolled students
Physics offered:		
Every year	76	93
Alternate years	13	4
Rarely or never	11	3
Schools not offering physics this year	18	6
Schools offering AP / 2nd year physics	25	42
Schools where half or more of physics teachers are specialists (defined by academic background and teaching experience)	33	45

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Table A-2. School and Physics Program Characteristics by School Type

	Public (%)	Private-Secular (%)	Private-"Mainstream" Religious (%)	Private-Fundamentalist (%)
Median size of senior class	179	51	106	26
% physics offered:				
Every year	78	75	92	47
Alternate years	12	15	6	26
Rarely or never	10	10	2	27
% of schools with physics offering single class in physics only	48	34	32	81
% of schools with physics offering advanced physics courses	24	40	31	7
% of students taking physics	31	79	62	43
% of students at school who are members of underrepresented minority groups	27	10	16	14
% of students taking physics who are members of underrepresented minority groups	20	10	12	13
Median funds available per physics class	$250	$463	$556	$218
% where half or more teachers are physics specialists	34	39	32	23
Median salary of physics teachers	$43,000	$44,000	$39,000	$28,500

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Table A-3. Characteristics of Physics Program by Size of Senior Class

	1-49 (35%)	50-199 (39%)	200-299 (11%)	300-499 (12%)	500+ (3%)
% of schools offering physics:					
Every year	49	85	94	97	100
Alternating years	28	7	4	2	
Never	23	8	2	1	
Number of physics classes (at schools with physics in 2005)					
1	85%	52%	21%	10%	6%
2	9	21	21	11	9
3	3	10	15	19	12
4 or more	3	17	43	60	73
% of schools with physics offering advanced physics courses	5	18	38	48	77
% of students taking physics	37	31	35	35	33
% of students at school who are members of underrepresented minority groups	17	20	24	28	33
% of physics students who are members of underrepresented minority groups	12	14	21	21	21
Number of physics teachers					
0	39%	12%	4%	1%	0%
1	59	77	65	54	31
2 or more	2	11	31	45	69
% of schools where half or more teachers are physics specialists	15	28	46	52	59
Median salary for physics teachers	$33,000	$41,300	$45,000	$49,500	$50,000

AIP Statistical Research Center: 2004-05 High School Physics Survey

Table A-4. Selected School Characteristics by Geographic Region

	North-east (5%)	Middle Atlantic (12%)	South Atlantic (14%)	East north central (17%)	East south central (7%)	West north central (13%)	West south central (14%)	Moun-tain (7%)	Pacific (11%)
% of schools in rural setting	29	22	22	31	37	63	46	49	20
Median seniors	140	115	133	110	80	42	60	43	126
% of students who are minority	14	21	31	16	28	9	40	26	36
% of physics students who are minority	9	13	26	14	14	5	32	19	28
% of students taking physics	39	34	21	27	12	24	28	19	21
% of schools with physics offering single class in physics only	24	26	42	48	72	72	54	57	37
% of schools with physics offering advanced physics	39	34	30	17	15	11	20	23	43
Median salary for physics teachers $000	48.0	50.0	40.0	45.0	38.5	36.0	38.0	39.0	52.0

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Table A-5. School Characteristics by Metropolitan Setting (Public Schools Only)

	Central city of large metro area	Suburbs of large metro area	Medium-sized metro area	Small city/large town	Rural
% of public schools	7	18	19	10	46
Median seniors	250	300	246	130	49
% of schools offering physics in 2005	83	96	90	84	76
Number of physics classes offered this year (at physics offering schools)					
1	17%	21%	24%	49%	73%
2 or more	83	79	76	51	27
% of students who take physics	37	30	30	20	26
% of students who are minority	59	25	25	21	15
% of physics students who are minority	51	19	18	13	10
Median salary for physics teacher	$49,700	$52,600	$47,800	$42,000	$40,600

AIP Statistical Research Center: 2004-05 High School Physics Survey

Table A-6. School Characteristics by Metropolitan Setting (Private Schools Only)

	Central city of large metro area	Suburbs of large metro area	Medium-sized metro area	Small city/large town	Rural
% of private schools	19	27	23	12	19
Median seniors	90	66	56	28	26
% of schools offering physics in 2005	83	79	80	71	60
Number of physics classes offered this year (at physics offering schools)					
1	31%	45%	54%	77%	79%
2 or more	69	55	46	23	21
% of students taking physics	62	62	61	61	53
% of students who are minority	23	12	10	5	10
% of physics students who are minority	15	11	8	8	8
Median salary for physics teacher	$43,200	$42,500	$36,500	$32,500	$30,600

AIP Statistical Research Center: 2004-05 High School Physics Survey

Table A-7. Characteristics of Physics Program by Socioeconomic Profile of School*
(Public Schools Only)

	Much better off than average	Somewhat better off than average	Average	Somewhat worse off than average	Much worse than average
% of schools offering physics:					
Every year	94	90	81	74	72
Alternating years	4	7	11	16	14
Never	2	3	8	10	14
Number of physics classes (at schools with physics in 2005)					
1	16%	32%	53%	54%	51%
2 or more	84	68	47	46	49
% of schools with physics offering advanced physics courses (AP + 2nd Year)	66	36	19	16	14
% of students taking physics	47	33	26	29	24
% of students at school who are members of underrepresented minority groups	10	16	23	38	58
% of physics students who are members of underrepresented minority groups	6	11	17	40	58
Number of physics teachers					
0	5%	6%	14%	19%	20%
1	41	65	73	68	69
2 or more	54	29	13	13	11
% of schools where half or more teachers are physics specialists	57	42	31	28	24
Median salary of physics teachers at school	$53,400	$49,000	$43,400	$43,400	$44,500

*Teacher/principal assessment of student economic circumstances relative to other schools in local area.

AIP Statistical Research Center: 2004-05 High School Physics Survey

APPENDIX B. SURVEY METHODOLOGY

The 2004-05 Nationwide Survey of High School Physics Teachers is the sixth in a series of studies begun by the American Institute of Physics in the mid-1980s, in response to concern expressed publicly both nationwide and within the physics community over the state of physics education in our nation's schools. The initial round of the survey was undertaken during the 1986-87 school year, with subsequent surveys in 1989-90, 1992-93, 1996-97 and 2000-01 and 2004-05. The findings of all five previous studies were discussed in final reports (Physics in the High Schools I & II, Overcoming Inertia: High School Physics in the 1990s, Maintaining Momentum: High School Physics for a New Millennium and Broadening the Base: High School Physics Education at the Turn of a New Century), which along with a number of shorter auxiliary reports and articles, are available free of charge from the American Institute of Physics.

The first four rounds of the study were conducted by contacting the same pool of 3000+ schools that made up a stratified sample of schools drawn in 1986. For more information on this initial sample drawing, please refer to the methodology section in the 1987 report. Because a small but not insignificant number of schools (especially the smallest ones) close every year, the number of schools in our sample had fallen every year. In 2001, a new sample was drawn. For more information about this re-draw, please see the methodology section from the 2001 report.

Prior to conducting the current round of the survey, the sample was "refreshed." This was achieved by obtaining the 2002-03 public school list from the Common Core of Data (CCD), a database of public schools maintained by the Department of Education's National Center for Education Statistics and the private school list from the Private School Survey (PSS), another database managed by NCES. Schools that were either not on the list previously (primarily new schools) or did not have seniors but now did in 1997-98 (the year where schools were originally drawn) but now did were isolated. From this list a one-sixth systematic sample was drawn and added to the pre-existing sample.

After the sample refreshment, principals at each of the sample schools were contacted to determine the presence or absence of a physics program. At the conclusion of this we had 3,426 sample schools (2621 public and 805 private) representing a 100% participation rate. Of this total, 2796 (82%) (2186 public and 610 private) offered physics. At these latter schools, principals identified 3,756 teachers who were teaching physics for the 2000-01 academic year, including 2,947 public and 809 private school teachers.

Each teacher listed by the principals was sent either an eight page questionnaire or an e-mail invitation (for those for which we had a valid e-mail address) asking them to fill out the questionnaire online. The questionnaire asked about their teaching experience and responsibilities, their school's physics program, their educational background and their future plans. Many of the questions were identical to those used in earlier rounds of the study, enabling us to track long-term trends. At the same time, questions were added that covered topics such as the existence and impact of Physics First, and the effects of the No Child Left Behind Act on teachers, students and the school's physics program. The teacher response rate was 62% – 33% online and 29% via paper – almost identical to what was attained in 2001.

Teacher Response Bias

One major source of error that can lead to a distorted picture in studies such as ours is response bias, resulting from systematic differences in relevant characteristics between those who responded to our survey and those who did not. Thirty-eight percent of the teachers in our sample did not complete the questionnaire in 2005. We can use ancillary sources of data to gain insight into teachers who did not respond in this round, allowing us to roughly gauge the potential magnitude and effect of some common sources of response bias.

Supplementary data sources, including the previous round of our own survey, contain information on the educational surroundings, personal background and current attitudes of many non-responding as well as responding teachers. On many school-level variables, describing the academic environment in which teachers work, we have data on virtually all sample teachers, both responders and non-responders. The information about schools was gathered from the original population database obtained from NCES, as well as from teachers responding in 2001 and from school principals.

Overall, we have heard from a substantial proportion of both our school and teacher sample, as shown in **Tables B-1** and **B-2**. While our participation rate for principals is 100%, as mentioned earlier, this provides only limited information on physics programs or physics teachers. However, due to the longitudinal character of the study, we have heard from at least one teacher at 81% of the sample schools since 2001, and these schools contain 88% of all high school students in the nation.

We also have information on a high proportion of the teachers in this year's sample. While we heard from 62% this year, when we augment our 2005 responders with those who answered in 2001, we have heard from 68% of those

Table B-1. Types of Information Available for 2005 School Sample

	% of schools with known characteristics
General characteristics of schools from CCD/PSS or reported by principal	100
Detailed description of current physics program and faculty characteristics at schools offering physics, from 2005 teacher respondents	68
Description of physics program and faculty at schools offering physics, from teacher respondents in 2005 or 2001	81

AIP Statistical Research Center: 2004-05 High School Teacher Survey

teaching high school physics in the U.S. in 2005. While this may not add to anything to our picture of teachers' current conditions and attitudes, it can help to fill in our knowledge of their background.

As **Table B-3** shows, a wide-ranging probe of this year's data revealed a few school-level differences between responders and non-responders. Among those that were found were a substantially lower response rate among teachers at fundamentalist schools and a slightly lower response from teachers at Southern schools, at schools that teach physics in alternate years, and at schools offer only 1 course in physics. No statistically significant differences were found between respondents and non-respondents in terms of geographic setting, grade range, or the number of teachers at the school.

In trying to account for the significant differences, we should note that schools offering physics in alternate years almost by definition are less likely to have a regular physics teacher. Thus, the teacher currently assigned to teach physics may feel less inclined to respond to a survey specifically devoted to that subject. A similar circumstance may account for the lower response rate at fundamentalist religious schools. Moreover, that underresponse, consistent in every round of the survey, has a small impact on our overall findings, simply because of the small percentage (around 1%) of the nation's high school students attending such schools. Schools in the South may have a lower response because of the overrepresentation of fundamentalist and secular private schools in their ranks.

Many, but not all, of the findings displayed in Table B-3 are consistent with response rate differences found in earlier years. In

Table B-2. Types of Information Available for 2005 Physics Teacher Sample

	% with known characteristics
School background information for teachers in the study:	
Characteristics of teacher's school derived from CCD/PSS file or principal response	100
Current characteristics of physics program derived from 2005 responses, including from colleagues at school	74
Long-term characteristics of physics program derived from teacher responses during 2005 or 2001	85
Information on personal characteristics of teachers:	
Detailed changeable personal characteristics	62
Permanent or long-term characteristics, derived from 2005 or 2001	68
Gender, from response or imputed from name	96

AIP Statistical Research Center: 2004-05 High School Physics Survey

2001, while considering school characteristics, we found lower response rates among teachers at fundamentalist religious schools (and at private schools in general), at Southern schools, schools that offered grades K-12, and schools that offered only one course in physics. In general, given the vast array of possible differences, response rate discrepancies by school background characteristics have been few and relatively muted throughout all the rounds of this study.

Table B-4 looks at response rates by gender for the entire sample. No significant differences in response were found by gender. Other personal characteristics of respondents and non-respondents were impossible to compare directly because there is no current information for non-respondents. The longitudinal character of the study does permit an indirect comparison that includes a subset of non-responders, namely those who had been in the sample and had responded in earlier rounds. Of course, there is no guarantee that findings for this subset are generalizable to all 2005 non-responders, but the analysis does provide us some critical personal data for a significant portion of this group and supports a weaker argument that those who responded some of the time have attributes that fall somewhere between those who always participated and those who never responded.

For 2001, (see **Table B-5**) we found differences in number of years teaching, number of years teaching at their current school, median years teaching physics, the percentage of those who would choose a different career, and the percentage that said insufficient funding for equipment and supplies is a serious problem.

Table B-3 Response Rates for Teachers by School Background Characteristics

	Respondents (2327) 62%	Non-Respondents (1429) 38%
School Type Ⓗ	**%**	**%**
Public	62	38
Private Secular	63	37
Private "Mainstream" Religious	67	33
Private Fundamentalist	49	51
Setting		
Central city of large metropolitan area	58	42
Suburbs of large metropolitan area	62	38
Small metropolitan area	64	36
Small city/large town	67	33
Small town/rural	60	40
Region Ⓗ		
South	59	41
North + West	63	37
Grade Range		
Senior high	63	37
Jr/Sr high	63	37
K-12	58	42
Physics Offered Ⓗ		
Every year	63	37
Alternate years	48	51
Socioeconomic Profile of School Ⓗ		
Much better off than average	71	29
Better off than average	63	37
Average	60	40
Worse off than average	62	38
Much worse off than average	59	41
Teachers at school		
1	62	38
2 or more	62	38
Number of Courses Taught at School Ⓗ		
1	57	43
2	64	36
3	67	33
4 or more	66	34

AIP Statistical Research Center: 2004-05 High School Physics Survey

Ⓗ Response rates significantly different at the .05 confidence level

Table B-4. Response Rates by Gender for Entire 2005 Sample

	Respon-dents	Non-respon-dents
Gender (%)		
Female	67	33
Male	64	36

AIP Statistical Research Center: 2004-05 High School Physics Survey

H Response rates significantly different at the .05 confidence level

Overall, the indications of response bias in this round is consistent with what has been found in previous rounds of the study. In light of this, we would argue that the findings discussed in this report provide a reasonably accurate picture of our sample. However the suggestions of response bias that *were* found, coupled with sampling, poor question wording, and other sources of potential inaccuracies, require that the findings still be interpreted with some caution, and dictate that our results continue to be scrutinized for inconsistencies and compared where possible with findings from similar studies.

Sampling Error

One further source of error which is typically described in great detail is sampling error, the extent to which the sample as selected does not accurately reflect the characteristics of the population from which it was drawn. Despite all the attention usually devoted to it (undoubtedly because of the relative precision with which it can be estimated), sampling error in a large study like this one tends to be only a modest contributor to overall error, compared to other error sources that are more difficult to measure but potentially far more threatening. Nevertheless, especially when considering and comparing smaller subgroups of the sample, sampling error can potentially weigh in strongly and must be taken into account when interpreting findings.

Most of the findings discussed in this report are presented in the form of simple proportions of schools or teachers. The estimated size of the sampling error of a proportion for a simple random sample varies with the magnitude of the particular proportion in question and the size of the sample or sub-sample under examination, and is given by the formula:

$$S=\left(\frac{P(1-P)}{n}\right)^{1/2}$$

For example, with a simple random sample, the estimate of sampling error for our finding that 76% of our sample schools offer physics every year would be given by:

$$S=\left(\frac{.76(1-.76)}{3426}\right)^{1/2}$$

Table B-5. Comparison of Respondents and Non-Respondents in 2005 on the Basis of Personal Information Supplied in 2001		
	Respondents (966)	**Non-Respondents** (220)
Median years teaching	11	14
Median years at school	6	9
Median years teaching physics	7	10
Median age	45	46
Median salary	$41,000	$43,000
Median % of seniors who take physics at school	31	32
% who would not again choose teaching as a career Ħ	11	13
% female	28	26
% with graduate degrees	69	64
% with physics or physics education degrees	39	34
% at schools with 2 or more teachers	36	37
% who are AAPT members	29	23
% planning to stay until retirement	88	84
% who say that insufficient funding for equipment & supplies is a serious problem Ħ	30	38
% who consider physics their specialty	62	62
% who are:		
specialists	37	31
career teachers	43	43
occasional teachers	20	26

AIP Statistical Research Center: 2000-01 & 2004-05 High School Physics Surveys

Ħ Percentages significantly different at the .05 confidence level

The confidence interval for this estimate is given by $\pm ZS$, where Z is the confidence coefficient. At the 95% confidence level used in this study, Z = 1.96 and the confidence interval for the finding that 76% of the schools offer physics every year would be ±1.5%. In other words, if we drew repeated samples of schools and posed the same question to principals each time, we would expect that 95% of the time we would come up with a proportion offering physics every year that fell within the range of 76% ±1.5%, or 74.5 to 77.5.

The stratified random sampling procedure used here yields error estimates that will vary slightly from those generated by a simple random sampling design and described by the above formula.

Stratification prior to sampling by itself generally reduces sampling error slightly, whereas disproportionate sampling of strata tends to heighten it, relative to a proportional sample of the same size (varying, of course, with the degree of disproportionality). The same holds true for findings involving means, where the 95% confidence interval is defined by $\pm 1.96s/n^{1/2}$, where s is the standard deviation of the distribution. (The finite population correction factor will be negligible due to the relatively large sample and low sampling rate, and has been omitted from the calculations above.) Finally, it should be noted that differences in proportions and means between groups (or lack of differences where large contrasts were expected) were generally made the focus of discussion in the body of the report only when they were substantial, in addition to being merely statistically significant.

The level of sampling error present in our estimates for findings derived from teacher responses is likely to be further compounded by the clustered sampling approach we employed, in which we sampled schools and then took a census of physics teachers at those schools. The increased error, relative to the levels likely if we had been able to sample from a pre-existing list of all physics teachers across the country, derives from the potential effect of a higher degree of homogeneity for many of our key variables among respondents at multi-teacher schools. For respondents who were the only physics teacher at their school, the overall impact of the heightened homogeneity of responses is likely to be small, but where we focus in our analysis on multi-teacher schools, the impact may be somewhat greater. In addition, there is higher risk of contamination at these schools as well, with teachers having more opportunity to discuss the survey and responses to specific questions with colleagues.

Other Errors

Other sources of error are also likely to be present in the survey, and some of these may be as great or greater than the kinds of error already discussed. Such other sources include:

a) Errors arising from poorly worded questionnaire items;

b) errors from poorly constructed or unduly complex questions;

c) errors in interpretation of questions or recall of answers by teacher respondents;

d) errors due to coder carelessness or mistakes in interpretation for both closed-ended and open-ended questionnaire items; and

e) errors in data entry and in statistical computation.

Of course, every effort has been made to double check responses against independent internal and external sources of data wherever possible, and to seek additional clarification or corroboration wherever discrepancies have arisen. For example, listings of physics teachers by principals were compared to teacher reports on the number of colleagues with physics assignments at the school. Any differences prompted a check of other teachers' responses and an immediate phone call to the school. Similar follow-up was undertaken in the case of discrepancies in the estimates of total number of seniors, number of physics classes and students taught by each instructor, and for several other key variables, as well. Other safety measures to guard against error included double entry verification of data for paper responses, and comparison of entered data to a scattered selection of survey instruments. These tests yielded a data entry error rate well below one-tenth of one percent.

Nevertheless, despite all such efforts, error from all the sources mentioned above is undoubtedly present in the data from which the findings were derived. In most instances, the final accuracy of the answers was impossible to cross-check. Overall error rates can thus never be determined with accuracy, and this requires that all findings be interpreted with suitable caution. While stability of findings among the 1986-87, 1989-90, 1992-93, 1996-97 and 2000-2001 studies increases the sense of confidence in a number of the conclusions drawn above, it will take repeated replication in future studies to permit a more accurate measure of the overall reliability of most of the findings discussed in this report. The results of the 2004-05 study have moved us one step further in that direction.

APPENDIX C.
STATES GROUPED BY GEOGRAPHIC REGION

New England
Connecticut
Maine
Massachusetts
New Hampshire
Rhode Island
Vermont

Middle Atlantic
New Jersey
New York
Pennsylvania

South Atlantic
Delaware
Florida
Georgia
Maryland
North Carolina
South Carolina
Virginia
West Virginia
District of Columbia

East North Central
Illinois
Indiana
Michigan
Ohio
Wisconsin

East South Central
Alabama
Kentucky
Mississippi
Tennessee

West North Central
Iowa
Kansas
Minnesota
Missouri
Nebraska
North Dakota

West South Central
Arkansas
Louisiana
Oklahoma
Texas

Mountain
Arizona
Colorado
Idaho
Montana
Nevada
New Mexico
Utah
Wyoming

Pacific
Alaska
California
Hawaii
Oregon
Washington

APPENDIX D. SURVEY INSTRUMENTS

1. Principal query form

2. 8-page physics teacher questionnaire

AMERICAN INSTITUTE OF PHYSICS
2004-05 HIGH SCHOOL PHYSICS SURVEY

Also available to complete online at: www.aip.org/statistics/hsphysics1

Even if your school is **NOT** offering courses in physics please answer all applicable questions.

1. Does your school offer a separate course in high school **physics** this year (2004-05)? ☐Yes ☐No

   If **No**, what was the primary reason why not? (check one)
   - ☐We teach it in alternate years
   - ☐Not an appropriate course for our school
   - ☐Not enough students want to take it
   - ☐Enough students, but no qualified teacher
   - ☐Other___________________________________

2. If **Yes**, please list all of the teachers with **PHYSICS** classes at your school **THIS YEAR** (Fall 2004 and/or Spring 2005), along with the number of **PHYSICS** classes they are teaching and their email addresses. If more than three teachers, please write additional names on the back.

	Name	Number of PHYSICS Classes this Year	Email Address
1.	___________________________	______	___________________________
2.	___________________________	______	___________________________
3.	___________________________	______	___________________________

3. Did your school offer a physics course *last year* (2003-04)? ☐Yes ☐No

4. In addition to any physics courses, how many classes of the following two courses does your school have this year? (if none, enter 0)

   Principles of Technology®______

   Integrated Physical Science (a single course combining physics with chemistry at the 9^{th}-10^{th} grade level)______

5. Some schools have changed the traditional order for teaching science, offering a full year of physics to 9^{th} graders before they take chemistry or biology. **Is your school using this "Physics First" approach this year?**
   - ☐No, we have never seriously considered teaching Physics First.
   - ☐No, we have considered teaching Physics First, but have no plans to implement it.
   - ☐Not yet, but we have definite plans to introduce Physics First in the next 3 years.
   - ☐Yes, we teach Physics First, but only for some 9^{th} graders (please answer 5a).
   - ☐Yes, we teach Physics First for all 9^{th} graders (please answer 5a).

   5a. If **yes**, how would you rate its impact so far? ☐generally positive ☐no major impact one way or the other ☐generally negative

6. How many seniors are there at your school this year?_________

7. What is your school's email address?_________________________ Do you have a website? www.________________

The final report for this study will be available online at www.aip.org/statistics/trends/hstrends.htm, and we will send you an announcement when it is issued. Would you also like to have a printed copy mailed to you when it is published? ☐Yes ☐No

AMERICAN INSTITUTE OF PHYSICS

2005 NATIONAL SURVEY OF HIGH SCHOOL TEACHERS OF PHYSICS

Dear Teacher,

Thank you for participating in the American Institute of Physics' National Survey of High School Physics Teachers. We are interested in hearing from all teachers with class assignments in physics this academic year, regardless of what field you may specialize in or how often in the past you may have taught physics.

If you are **NOT** teaching any physics classes this academic year, PLEASE CHECK HERE ☐ and return this questionnaire blank in the enclosed envelope.

This questionnaire consists of four sections, and should take you about 20 minutes to complete. In SECTION A, we ask you to describe your past experiences and current assignment as a teacher.

This survey may also be completed online at: www.aip.org/statistics/hsphysics2

SECTION A: TEACHING EXPERIENCE AND RESPONSIBILITIES

1. How many years (counting this year) have you taught:

a. at the HIGH SCHOOL level? _____ years

b. in THIS school? _____ years

2. How many years (counting this year) have you taught one or more HIGH SCHOOL courses in the following subjects?

Subject	Years Teaching	Subject	Years Teaching
a. Physics	_____	d. 9th Grade Level Physical Science	_____
b. Chemistry	_____	e. Other HS-Level Science or Technology	_____
c. Biology	_____	f. Mathematics.	_____

3. What would you describe as your PRIMARY subject area of specialization up to this point in your teaching career? (Please check only one.)

- ☐ Physics
- ☐ Chemistry
- ☐ Any Other Science, specify: ____________________
- ☐ Math
- ☐ Other Subject, specify: ____________________

4. **In recent years, some schools have introduced block scheduling for at least some of their courses. How are your <u>PHYSICS</u> courses scheduled this year?**

- ☐ a. regular 40-60 minute periods every day, all year
- ☐ b. block scheduled double periods, offered on alternate days for the entire year (A-B — A-B)
- ☐ c. block scheduled double periods, offered every day → ☐ spring only ☐ fall only (please fill out 5a1 below) ☐ both semesters, to a new group of students this spring
- ☐ d. other, please specify: ____________________

5. **How many CLASSES and STUDENTS are <u>YOU</u> teaching this term (SPRING 2005). Please include only the classes you yourself are teaching. Do not count labs as a separate class.**

	Number of classes you have this term	Number of students in those classes
a. Physics	____	______
a1. If you checked box 4c above, also enter totals for last FALL's Physics	____	______
b. Chemistry	____	______
c. Biology	____	______
d. Applied Science / Principles of Technology	____	______
e. 9th Grade Level Physical Science or Integrated Physics / Chemistry	____	______
f. Other HS-level Science or Technology, specify: ____________________	____	______
g. Mathematics	____	______
h. All Other Subjects, specify: ____________________	____	______
TOTAL FOR ALL SUBJECTS (sum a through h)	____	______
	Classes	Students

SECTION B: PHYSICS INSTRUCTION AT YOUR SCHOOL

6. **Approximately how many students are taking a physics class in your school this academic year? (Please count all physics classes, including those taught by other teachers.)** ________

7. **Are there any <u>other</u> teachers teaching physics at your school <u>this</u> term?** ☐ no ☐ yes, how many <u>other</u> teachers? ____

8. **Are there any <u>other</u> teachers who taught physics <u>last fall</u> but are <u>not</u> teaching it now?** ☐ no ☐ yes, how many? ____

9. **Approximately what percentage of the students in JUST YOUR OWN PHYSICS CLASSES this year are:**

White	_____%	Seniors	_____%	Male	_____%
Black	_____%	Juniors	_____%	Female	_____%
Hispanic	_____%	Sophomores	_____%		=100%
Asian	_____%	Freshman	_____%		
Other	_____%		=100%		
	=100%				

10. Compared to the other high schools in your entire metropolitan area (or county, if you are located outside a metropolitan area), how would you rank the economic circumstances, on average, of your school's student body?

- ☐ Much better off than average
- ☐ Somewhat better off than average
- ☐ About average
- ☐ Somewhat worse off than average
- ☐ Much worse off than average

11. When your students first entered your class, how prepared were they to take physics in terms of:

	Inadequately Prepared	Adequately Prepared	Very Well Prepared
a. Math background	☐	☐	☐
b. Physical Science background	☐	☐	☐
c. Ability to think and pose questions scientifically	☐	☐	☐
d. Familiarity with general laboratory methods	☐	☐	☐
e. Use of computers in science	☐	☐	☐

12. How has the overall preparation of your entering physics students changed compared to four years ago?

☐ Improved ☐ Stayed about the same ☐ Declined

13. Now we would like to turn to the specific physics courses that you yourself are teaching this term (or for the entire year, if you checked Question 4c).

Enter total number of classes and students for each type of physics course. (Please do not include labs as a separate course.)
Indicate texts by code # from the list below, up to 2 per course, and rate your satisfaction with them, from 1=poor to 5=excellent.

Type of Physics Course	# of Classes	# of Students	Text Code #	Rating 1-5	Text Code #	Rating 1-5
a. Regular First-Year Physics	___	___	___	___	___	___
b. Physics for Non-Science Students / Conceptual Physics	___	___	___	___	___	___
c. First Year Honors / Accelerated / Gifted and Talented Physics	___	___	___	___	___	___
d. Advanced Placement Physics B	___	___	___	___	___	___
e. Advanced Placement Physics C	___	___	___	___	___	___
f. Second Year Physics (NOT AP)	___	___	___	___	___	___
g. Other Physics, specify: ________	___	___	___	___	___	___
TOTAL PHYSICS (The total number of classes and students should match the combined total for questions 5a + 5a1)	___	___				

Physics Textbook Code #s

1. Active Physics (Eisenkraft / *It's About Time*)
2. College Physics (Serway and Faughn / *Brooks - Cole*)
3. College Physics (Wilson and Buffa / *Prentice Hall*)
4. Conceptual Physics [HS Level] (Hewitt / *Addison Wesley*)
5. Conceptual Physics [College Level] (Hewitt)
6. Fundamentals of Physics (Halliday, Resnick & Walker / *Wiley*)
7. Holt Physics (Serway and Faughn / *Holt*)
8. Modern Physics (Trinklein / *Holt*)
9. Physics (Cutnell and Johnson / *Wiley*)
10. Physics: Principles & Problems (Zitzewitz / *Glencoe - McGraw*)
11. Physics Principles with Applications (Giancoli / *Prentice Hall*)
12. PSSC Physics (Haber-Schaim et al. / *Kendall-Hunt*)
13. University Physics (Sears and Zemansky)
14. Other text #1: ________
15. Other text #2: ________
16. Academic software: ________
17. Academic videos: ________
18. Other materials: ________

14. If you teach Advanced Placement Physics, what percentage of the students in that class had already taken a full-year of high school physics?

AP-B ______% AP-C ______%

15. Do you or any other physics teachers at your school teach a physics class (not physical science) to just 9th graders?

- ☐ a. No, neither I nor any other teacher teaches a physics class to just 9th graders. **(skip to question 20)**
- ☐ b. I don't, but other teachers do. **(continue to question 16)**
- ☐ c. I do, but no other teachers do. **(continue to question 16)**
- ☐ d. I do, and so do other teachers at this school. **(continue to question 16)**

16. If you answered b, c, or d on question 15, which 9th graders take this physics class?

- ☐ every 9th grader at the school
- ☐ only the more scientifically advanced 9th graders
- ☐ only the less scientifically advanced 9th graders
- ☐ only some 9th graders, but drawn from across the ability range

17. Which science class do students generally take after 9th grade physics?

☐ chemistry ☐ biology ☐ other: ______________________

18. How do you feel about the switch to 9th grade physics so far?

☐ very positive ☐ somewhat positive ☐ somewhat negative ☐ very negative

19. Please describe the impact on yourself, other teachers, and / or the students.

____

____

20. Below is a list of "non-traditional" approaches to physics teaching that have appeared in recent years. Please put a check next to any that you formally use in place of more traditional instruction.

- ☐ I don't use any non-traditional approaches.
- ☐ Active Physics®
- ☐ C^3P® (Comprehensive Conceptual Curriculum for Physics)
- ☐ CPU® (Constructing Physics Understanding)
- ☐ Interdisciplinary Instruction, specify disciplines: ______________________
- ☐ Modeling Instruction Program®
- ☐ Physics by Inquiry®
- ☐ Real Time Physics®
- ☐ Workshop Physics®
- ☐ Other "New Approaches", specify below: ______________________

21. If you use any of these non-traditional approaches, please elaborate on their effectiveness.

____

____

22. **Have the student-testing provisions in the *No Child Left Behind Act* affected your physics classes or curriculum? (If yes, please tell us how.)**

☐ No ☐ Yes, Positively → ____________________
☐ Yes, Negatively → ____________________

23. **Have the provisions on teacher qualification in the *No Child Left Behind Act* affected you as a teacher? (If yes, please tell us how.)**

☐ No ☐ Yes, Positively → ____________________
☐ Yes, Negatively → ____________________

24. **Has there been any other impact on you, your physics students, or your school's physics program stemming from the *No Child Left Behind Act*?**

☐ No ☐ Yes, please describe: ____________________

25. **Have any of the following impacted your physics teaching? (If yes, please explain briefly in the space to the right.)**

a. Collaboration with a college or university ☐ No ☐ Yes ____________________
b. Physics Education Research (PER) ☐ No ☐ Yes ____________________

26. **Which of the following are problems that affect your physics teaching?**

	Not a Problem	Minor Problem	Serious Problem
a. Inadequate space for lab or lab facilities outmoded	☐	☐	☐
b. Insufficient funds for equipment and supplies	☐	☐	☐
c. Difficulties in scheduling classes and labs	☐	☐	☐
d. Not enough time to plan lessons	☐	☐	☐
e. Not enough time to prepare labs	☐	☐	☐
f. Insufficient administration support or recognition	☐	☐	☐
g. Students do not think physics is important	☐	☐	☐
h. Inadequate student mathematical preparation	☐	☐	☐

27. **How much money for physics equipment and supplies was available to you <u>for just your own physics classes and labs</u> from all school sources for the current academic year?**

$____________

28. **Is any of the following equipment available to the students in your physics courses? If yes, how adequate is the supply, and how well-prepared are students to use it when they begin your courses?**

	Available at School?		Supply Adequate	Supply Inadequate	Students Generally Prepared	Students Generally Unprepared
a. Graphing calculators	☐ No	☐ Yes	☐	☐	☐	☐
b. Computers for student use	☐ No	☐ Yes	☐	☐	☐	☐
c. Specialized physics software	☐ No	☐ Yes	☐	☐	☐	☐

29. Please indicate the extent to which you agree with each of the following statements.

	Agree Strongly	Agree Somewhat	Neither Agree Nor Disagree	Disagree Somewhat	Disagree Strongly
a. I prefer teaching physics to teaching other subjects.	☐	☐	☐	☐	☐
b. All students should take a physics course in high school.	☐	☐	☐	☐	☐
c. Conceptual physics enrollments in my school have grown at the expense of algebra / trig physics.	☐	☐	☐	☐	☐
d. I have ample opportunity to share ideas with other physics teachers.	☐	☐	☐	☐	☐
e. Only people who majored or minored in physics in college should be allowed to teach it in high school.	☐	☐	☐	☐	☐
f. If I had it to do over again, I would still choose high school teaching as my career.	☐	☐	☐	☐	☐
g. The sequence of high school sciences should be reversed, so that students take physics first, before chemistry or biology.	☐	☐	☐	☐	☐

30. What aspects of your work as a high school physics teacher do you find <u>most</u> satisfying?

____

____

31. What aspects of your work as a high school physics teacher do you find <u>least</u> satisfying?

____

____

SECTION C: YOUR BACKGROUND AND EDUCATION

32. Please indicate ALL college <u>degrees</u> you have earned, the year each degree was awarded, and the code letter from the list on the right for your major area of study (and minor, if any) for each degree.

If you had a full double major, list as two separate degrees earned in the same year.

If you are <u>currently</u> enrolled towards a degree, please check here ☐ and enter the expected degree date in the "year earned" space.

	Year Earned	Major Code	Minor Code
Bachelors	______	___	___
2nd Bachelors	______	___	___
Masters	______	___	___
2nd Masters	______	___	___
Doctorate	______	___	___

SCIENCE / MATH MAJORS

A. Physics (NOT Physics Education)

B. Chemistry (NOT Chemistry Education)

C. Biology / Life Science (NOT Biology Education)

D. Other Science (NOT Science Education)
specify: ______________________

E. Mathematics / Engineering / Computer Science

EDUCATION-RELATED MAJORS

F. Physics Education

G. Chemistry Education or Physical Science Education

H. General or other specific Science Education

I. Math Education

J. Other Education / Administration / Counseling

K. Other Major #1
specify: ______________________

L. Other Major #2
specify: ______________________

33. How many semesters (not credit hours) of the following courses did you take in college? (If you were on the quarter system, divide the number of semesters by 2.)

	Semesters As an Undergraduate	Semesters As a Graduate Student
a. Introductory-level Physics Courses	____	____
b. Post-Intro Physics Courses	____	____
c. Courses on Physics Teaching	____	____
d. Other Physics Courses, please list: ______________________	____	____

34. How well-prepared do you feel you are in each of the following aspects of physics teaching?

	Not Adequately Prepared	Adequately Prepared	Very Well Prepared
a. Basic physics knowledge	☐	☐	☐
b. Recent developments in physics	☐	☐	☐
c. Other science knowledge	☐	☐	☐
d. Instructional laboratory design and demonstrations	☐	☐	☐
e. Use of computers in physics instruction and labs	☐	☐	☐
f. Application of physics to everyday experience	☐	☐	☐

35. Approximately what is your regular teaching salary for this school year? $______________

Please include your base salary only. Exclude any supplemental earnings or bonuses for extracurricular duties.

If you are working only **part-time,** please check here ☐.

If you are receiving room and / or board or a "religious salary," please check here ☐.

36. Are you a member of any professional organizations at either the National, State or Local level?

	National		State or Local	
a. AAPT (American Association of Physics Teachers)	☐ yes	☐ no	☐ yes	☐ no
b. NSTA (National Science Teachers Association)	☐ yes	☐ no	☐ yes	☐ no
c. Other, specify: ______________________	☐ yes	☐ no	☐ yes	☐ no

37. Are you currently part of: (check any that apply)

☐ A formal group of science teachers (outside of the above organizations) that meets regularly to discuss classroom issues

☐ An Internet list-serve or Internet discussion group for physics or science teachers

☐ Any other forum for discussing physics education. Please specify: ______________________

38. If you have a question about physics content, where do you go for an answer? Please rank the top three by entering one letter in each. If you don't go anywhere, check here ☐.

_____ Most Likely Place to Turn   _____ 2nd Most Likely   _____ 3rd Most Likely

a. High School Physics Textbooks
b. College Physics Textbooks
c. Other High School Physics Teachers
d. College or University Teachers
e. Research Scientist Acquaintances
f. World Wide Web
g. Internet Group (e.g. list-serve)
h. Other, specify: ______________________

39. **Did you attend any of the following during calendar year 2004? (Please count only those events lasting at least one-half day.)**

	Not in 2004	Yes, One Time	Yes, More Than Once
a. Workshop on physics classroom instruction techniques	☐	☐	☐
b. Workshop on physics lab design or delivery	☐	☐	☐
c. Professional association local or national meeting.	☐	☐	☐
d. Other, specify: ________________________________	☐	☐	☐

40. **What year were you born?** __________

41. **Are you:** ☐ Female ☐ Male

42. **What racial or ethnic group do you belong to?**

☐ White ☐ Black ☐ Hispanic ☐ Asian ☐ other, specify: ______________________

SECTION D: YOUR PLANS FOR THE FUTURE

43. **How many more years do you expect to teach high school? (check one)**

☐ This is my last year ☐ 1 to 5 years ☐ 6 to 10 years ☐ 11 to 19 years ☐ 20 or more years

44. **Do you plan to remain in high school education until retirement or are you hoping to change careers prior to that point?**

☐ I am planning to remain until I retire.
☐ I am hoping to change careers prior to retirement.

45. **Do you have Internet access:** ☐ at home ➔ E-mail address: ______________________________

☐ at school ➔ E-mail address: ______________________________

46. **Both the highlights and the full Final Report from this survey will be available on the AIP website at *www.aip.org/statistics/trends/hstrends.htm* when the study is completed.**

Would you also like to receive a paper copy of the Final Report when it is released?

☐ No ☐ Yes ☐ Send to me at school (address correction below only if mailing label was incorrect)

☐ Send to me at home (please provide address below)

Name ____________________________________

Address ____________________________ City ____________________ State ________ Zip __________

We would appreciate any additional comments you might have on your experience as a physics teacher, as well as any comments on this survey. Please use an additional sheet of paper if necessary.

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