Towards a high quality high school workforce: A longitudinal, demographic analysis of U.S. public school physics teachers

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Efforts to improve the number and quality of the high school physics teaching workforce have taken several forms, including those sponsored by professional organizations. Using a series of large-scale teacher demographic data sets from the National Center for Education Statistics (NCES), this study sought to investigate trends in teacher quality at the national level in the two and a half decades between 1987 and 2012. Specifically, we investigated (i) details about the degree backgrounds, main teaching assignments, and experience levels of those assigned to teach physics; (ii) whether the proportion of those with certifications in physics as a fraction of the entire physics teaching workforce had changed; and (iii) if workforce diversity (with respect to race and gender) had changed over time. Our data indicate that trends in these domains have generally been positive, but still fall short of having a highly qualified physics teacher in each classroom. Additionally, the population of physics teachers has more novices and fewer veterans than it did 10 years ago, although veteran physics teachers are not as rare as those in other branches of high school STEM fields. We also analyzed trends in physics teacher race and gender diversity and found them to lag behind other STEM and non-STEM teacher communities. High school physics is still mostly taught by white males with backgrounds from outside of physics. Implications for future policy decisions at the local and national levels are discussed, including attending to the specific needs of degree-holding and non-degree-holding physics teachers separately and localizing teacher recruitment and preparation efforts in regional centers.

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I. INTRODUCTION

Student enrollment in high school physics has seen a dramatic increase over the last 30 years [1]. Annually, more than one million students are enrolled in introductory physics courses in U.S. high schools and the American Institute of Physics (AIP) estimates that 39% of high school students complete a physics course before graduating [1]. After the publication of the *A Nation at Risk* report in the early 1980s, many states increased their science and mathematics graduation requirements so that states requiring just one year of science to graduate prior to this report increased requirements to two or three years [2–4]. Additionally, the AIP reported that increased student enrollment in physics could be attributed to recent implementations of conceptual physics or "Physics First" and AP physics courses [1].

However, this rise in physics enrollment is not necessarily beneficial, particularly for students with underqualified physics teachers. Therefore, increasing the number of students taking physics has important consequences for educators and the policies that influence the preparation of physics teachers nationwide. In this article, we attempt to characterize the quality of the physics teaching workforce in U.S. public high schools and detect changes in physics teacher demographics at the national level over time. An understanding of physics teacher demographics will help to inform future decisions regarding the most effective means of ensuring highly quality educators are leading our K–12 physics classrooms.

II. BACKGROUND AND PRIOR RESEARCH

The idea that teacher quality impacts student performance is neither surprising nor controversial. Several studies have reported a positive correlation between teachers with strong qualifications and student achievement in STEM. At the national level, Darling-Hammond determined that several factors, including (i) degree in the field being taught, (ii) certification status, (iii) teaching experience, (iv) subject matter knowledge, and (v) knowledge of teaching and learning, impact student performance in STEM [5]. Those teachers with regular certifications and in-field degrees were determined to have the most beneficial impact on student achievement. Additionally, race and gender congruity between teachers and students has been also associated with increased student performance in STEM. Dee and co-workers cited the effect of teacher-student diversity pairings on student performance and found that congruous pairings were positively impactful, especially for young women of color [6].

However, two aspects of teaching high school physics have historically set it apart from other STEM subjects: (i) most physics teachers are isolated from other physics teachers; even today, in 80% of high schools where physics is taught, a single instructor is solely responsible for teaching all physics courses [7], and (ii) due to the relatively few physics courses offered in most schools, these teachers do not usually teach physics classes exclusively [8]. Understandably, many schools with low enrollments and low numbers of physics course sections have outsourced these courses to other STEM teachers. Consequently, physics has often been taught by three categories of nonphysics teachers:

(a) those who are teaching without a physics license (e.g., physics degree holders who are uncertified to teach physics),
(b) teachers who are teaching out of field (e.g., mathematics teachers who hold mathematics degrees), and
(c) teachers who hold emergency licenses (e.g., teachers lacking pedagogical training).

To gain a better sense of who teaches high school physics across the nation, the AIP has conducted a series of surveys of approximately 3500 U.S. public and private school high school teachers in order to analyze the educational preparation and gender demographics of physics teachers [7–10]. These AIP reports offer details of several characteristics of the physics teaching workforce, including teaching experience, main course assignment, affiliations with professional physics organizations, and preferred teaching methods. Longitudinal data are reported for changes in physics teacher-to-students counts, percent of physics teachers with a major or minor in field, main assignments in physics, and the percentage of females teaching physics. However, long-term trends in certification status and teaching experience have not yet been reported. Additionally, these studies lack details about the specific academic majors and non-physics main assignments of the workforce. For example, since physics as a subject has been historically outsourced to other teachers, it might be helpful to know the degree backgrounds and main course assignments of these teachers in order to more specifically inform future policy decisions and reform efforts aimed at improving the preparedness of physics teachers. Similarly, information regarding longitudinal trends in the racial distribution of the workforce might serve to validate or improve efforts aimed at increasing the diversity of the profession.

III. STUDY CONTEXT

This study complements and improves upon the previously summarized AIP surveys by using the Schools and Staffing Survey (SASS) as the sampling measure and focusing on quantifying the changes in the quality of U.S. K–12 physics education. We consider longitudinal trends in teacher quality metrics over a twenty-five year period between 1987 and 2012, including degree background, in-field certification, and experience in comparison to other STEM fields (i.e., biology and chemistry) over the same time. Using data from the SASS, this study is additionally able to assess the extent to which the physics teaching workforce has been able to diversify in race and gender over this time frame. Herein, we consider the longitudinal trends in the public high school physics teachers and teachers of physics over this twenty-five year period by considering the following research questions:

(1) To what extent have teachers with physics degrees been able to teach physics relative to other subjects as their main teaching assignment?
(2) How has the proportion of physics degree-holding teachers teaching physics changed?
(3) What has been the certification status of physics teachers over time?
(4) What are the trends in teaching experience for physics teachers?
(5) How has the racial distribution of all physics teachers changed over time?
(6) How has the gender distribution of all physics teachers changed over time?

As the National Task Force on Physics Teacher Education reported, "the need for qualified physics teachers is greater now than at any previous time in U.S. history." [11]. A better understanding of recent shifts in and the demographic makeup of past and current physics teachers in the classroom should inform stakeholder decisions regarding efforts to recruit, prepare, support, and retain new and existing physics teachers.

IV. DATA SOURCES AND ANALYTICAL METHODOLOGY

Our research is based on the SASS, a national system of related surveys that provide quantitative data on the elementary and secondary education system in the United States [12]. SASS is conducted by the National Center for Education Statistics (NCES) and is the largest survey of U.S. K–12 school districts, schools, teachers, and administrators. The survey has been administered in seven of the past thirty years (1987-88, 1990-91, 1993-94, 1999-2000, 2003-04, 2007-08, and 2011-12) for the purpose of characterizing elementary and secondary education for policymakers. We analyzed data from responses to questionnaires sent to teachers that included questions about their workload, training, and other related information. Physics teachers were defined as those reported to be teaching at least one physics course. The STEM population includes all teachers responsible for science, technology, engineering, or mathematics classes excluding physics, while the non-STEM group is composed of all other secondary teachers. Our analysis of specific teacher demographics was informed by previous studies on STEM teacher quality [5,6]. We therefore understood a high-quality physics teacher workforce to be one that is (i) made up of qualified teachers with an in-field major or minor and in-field certifications, (ii) experienced, and (iii) diverse (with respect to both race and gender).

An important component of SASS is the inclusion of final weights as well as replicate weights to allow for estimates of the national number of teachers while accounting for non-response bias and the complex survey design. The replicate weights allow for calculation of the standard error of the estimates of the final weight using the balanced repeated replication (BRR) methodology [13,14]. Additional details on the BRR methodology and data preparation can be found in the previous studies on chemistry and biology and in Supplemental Material, part A [15]. SAS version 9.3 was used for all of the calculations while most of the graphics were constructed in R version 3.0.3 [16].

V. RESULTS

A. Teaching assignments for physics teachers

The extent to which physics teachers with a degree in physics were assigned to teach physics classes is likely the most important segment of the physics teaching population to study. Those with strong content backgrounds are likely to become amongst the best prepared to teach physics and have the intrinsic motivation to improve their practice over time [17–19]. Having a deep understanding of the content provides a platform upon which to establish pedagogical content knowledge (PCK) while weak content knowledge is less likely to yield strong PCK, as it is often defined as an amalgamation of these two distinct constructs [20].

We reasoned that if most of the physics teachers from physics backgrounds were not assigned to teach physics (possibly due to a lack of demand for the course or the perceived need to staff other ‘required’ classes), then the historical challenges with recruiting from physics departments (i.e., the difficulty of recruiting physics degree holders to teach physics) might have an underlying cause that is not present in other core STEM subjects (e.g., biology, chemistry, mathematics). While SASS has asked respondents to self-report their main teaching assignment, the lack of a clear definition of “main” in the survey question (i.e., majority assignment, primary assignment, self-identified preferred assignment) coupled with changes in survey design over the years have made this data difficult to interpret with high consistency. We therefore chose to define teachers’ main assignment as the subject comprising more than 50% of their teaching load in their most recent full week of teaching as determined by their self-reported class load data. To investigate how well correlated the in-field teaching assignments were for physics teachers with a degree in physics, we plotted the percentage of physics classes taught compared to other courses for (i) all teachers reported to have earned at least a bachelor’s degree in physics and who taught at least one physics class in their most recent full week of teaching that survey year, and (ii) the subgroup of this population reporting a main assignment in physics (i.e., those teaching 50% or more physics courses as determined by teachers’ reported class load data). These results, shown in Figs. 1(a) and 1(b), reveal a promising shift for both populations. In Fig. 1(a), the percentage of physics courses taught by physics degree holders rose in four of the five reported survey years, from a low in 1993 ($\sim$31% physics classes) to approximately 45% by 2011. The proportion of physics degree-holding teachers that reported teaching no physics courses in 2011 was found to be 40% (data not shown). Only three other courses outside of physics were reported as being taught as more than 10% of the class load in any survey year: mathematics, chemistry and “other STEM” (e.g., physical science, Earth or space science). As physics assignments have increased over time, there has been a concomitant decrease in the proportions of both mathematics and chemistry course assignments. For those physics degree holders reporting a main assignment in physics [Fig. 1(b)], the shift towards a greater emphasis on physics compared to other classes over time is also evident, although less pronounced. In all survey years since 1993, physics has been taught as >70% of the class load, rising to over 75% in 2011. For this group of teachers, only the other STEM category ($\sim$15%) consistently accounted for a significant proportion of the classes outside of physics, and both have decreased over time.

B. Content backgrounds for teachers of physics

Since the turn of the century, the primary emphasis in physics teacher education reform has been to mobilize physics departments to improve the quantity and quality of the high school teaching workforce. To gauge how the content background of our nation’s physics teachers have changed over time, we plotted the reported degree backgrounds of all teachers who (a) taught at least one physics course their most recent full week of teaching for a given survey year and (b) for the subgroup of this population who reported a main assignment in teaching physics. We anticipated the number of physics teachers with physics degrees to be relatively low, but were unaware of any

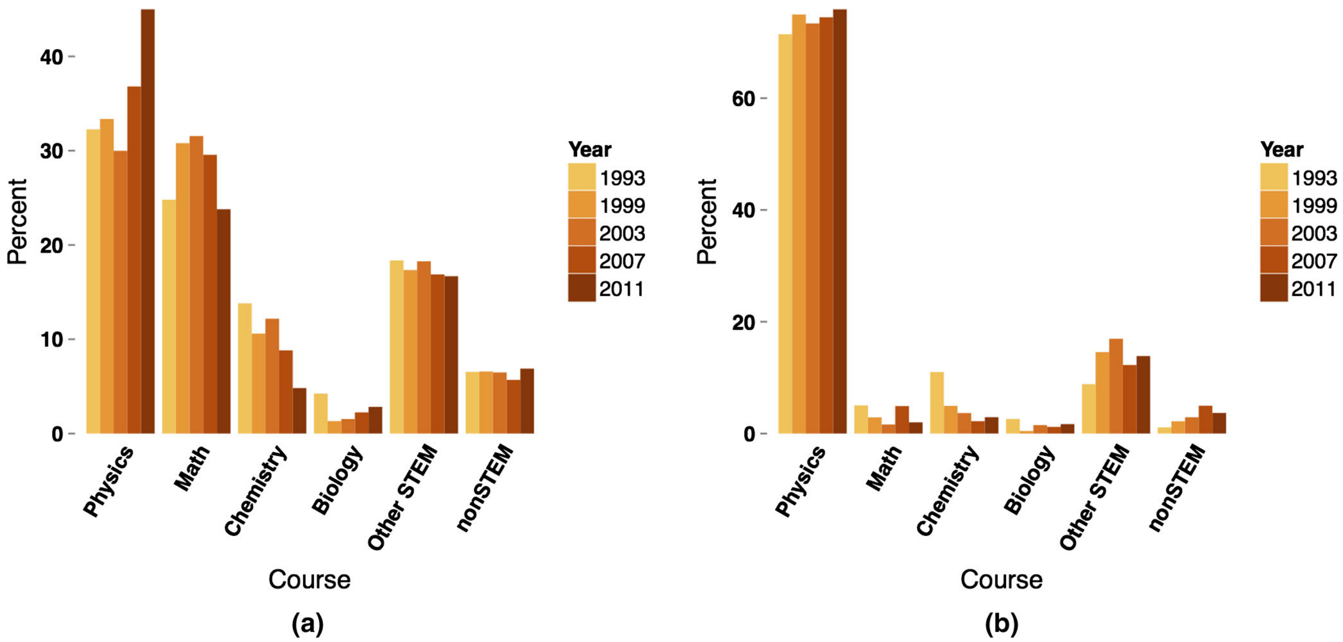

FIG. 1. Distribution of courses taught by (a) physics teachers with a physics degree (standard error ≤5.7%) and (b) physics teachers with a physics degree and a main assignment in physics (standard error ≤6.8%) calculated for the five most recent survey years. Physics degree holders alone are not considered in this analysis.

longitudinal studies of this parameter. We considered physics minors or degrees as such, regardless of the type of college or department that granted the minor or degree. These results, shown in Figs. 2(a) and 2(b), respectively, indicate that over the twenty year period between 1993 and 2011, the proportion of physics teachers who reported having a minor in physics or earning a degree in physics (at the bachelor's level or higher) exceeds 25% only in more recent survey years, with similar values obtained by AIP [10]. Although the proportion of physics teachers reporting in-field degree backgrounds is the lowest of the three core science disciplines we have analyzed to date

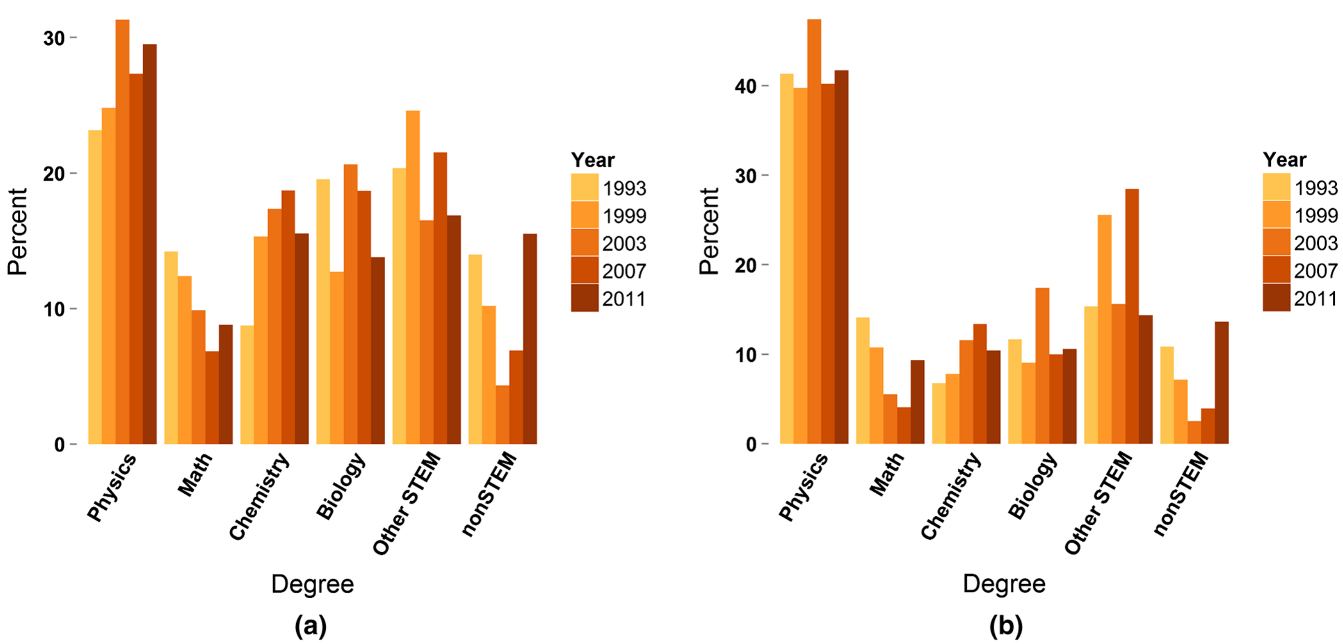

FIG. 2. Proportions of reported degree (or minor) of (a) physics teachers (standard error ≤4.48%) and (b) teachers with a main assignment in physics (standard error ≤7.17%) calculated for each survey year. Data is unavailable prior to 1993 due to a change in the survey design.

[19,21,22], in-field teachers have been increasingly more prominent: from a low of ∼15% in 1990 but increasing over the previous survey year in four of the seven available time points [Fig. 2(a)]. Further, in the first two survey years (1987, 1990), biology degree-holding teachers were more likely to be teaching physics than those with an in-field degree, though by 2011, both groups were equally likely to be teaching physics.

Additionally, physics (in contrast to biology and chemistry) has drawn from a significantly more diverse range of STEM majors. Over the past two decades, physics has had at least 10% of its teachers from one of five different out-of-field (non-physics) backgrounds, compared to just two for the biology and chemistry teaching communities [19,21]. While the reliance on chemistry and mathematics degree holders to teach physics has declined, reliance on biology degree holders has remained fairly consistent at roughly 20% (1 in 5 physics teachers), with fluctuations in 1999 and 2011. In contrast, physics teachers reporting degrees in technology and engineering have continued to increase, reaching a maximum of 10% in 2007.

For main assignment physics teachers (>50% of course load in physics), the fields from which their degrees are drawn are consistent with the overall physics teaching population, but with higher proportions from physics degrees and less from the out-of-field disciplines. The general shift for main assignment physics teachers reporting earned physics degrees has been upward since 1987, and over the past decade, approached or exceeded 40% (i.e., 2 out of every 5 teachers) in two of the last three survey years (2003 and 2011). This proportion of main assignment teachers from in-field backgrounds is comparable to that of chemistry teachers, but lags behind biology's proportion of more than two-thirds (∼70%) [19]. The contribution of other fields to main assignment physics teaching has remained relatively constant in the range of 10%–15% for each field but, in the last ten years, this population appears to be decreasingly comprised of those from mathematics backgrounds.

C. Main assignments for all physics teachers

The main assignment for physics teachers has historically not been physics, but rather other STEM courses as most are teaching out of field [Figs. 2(a),3(a)]. Between 1987 and 2011, the proportion of teachers with physics main assignments has generally increased but exceeded 50% only once, in 2011. These values are quite consistent with those reported by AIP [10]. Figure 3(b) depicts the top five nonphysics main assignment subjects reported by physics teachers. Chemistry assignments have averaged between 30% and 40%, and as such has been the most common nonphysics main assignment in every survey year; mathematics and biology have generally made up between 10% and 20% each. The remaining 35%–45% are distributed between the collective other STEM category (see Supplemental Material [15] for complete list) and non-STEM courses, further illustrating the extent to which physics is taught as an occasional subject. One interpretation of these observations is to consider the type of teacher being defined by his or her main assignment: a

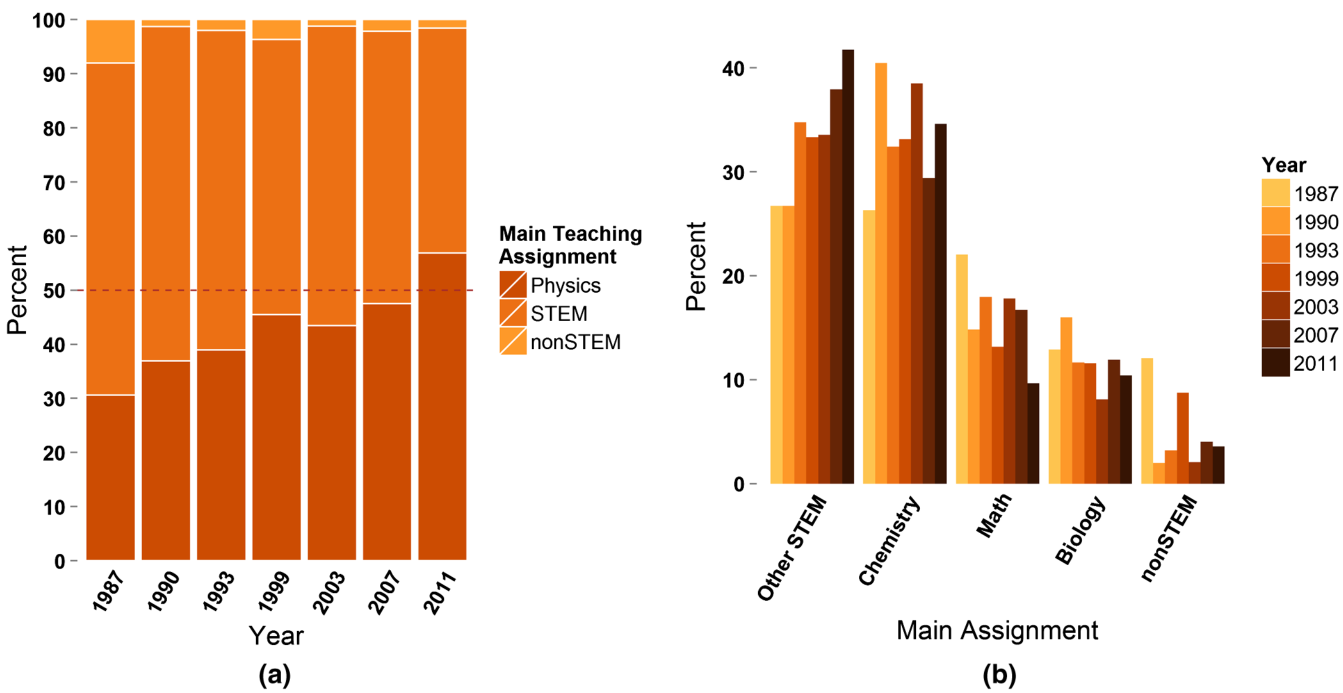

FIG. 3. (a) Main teaching assignments for all physics teachers between 1987 and 2011 (standard error ≤4.38%). (b) Top five nonphysics main assignments for each survey year (standard error ≤6.63%).

physics teacher who teaches chemistry most of the day might be perceived by him or herself or by others to be a "*chemistry teacher with a section or two of physics*" rather than a "*physics teacher who mostly teaches chemistry*." From this perspective, in every survey year except 2011 physics has predominantly been taught by nonphysics specialists, as defined by their course assignment. As is discussed later, thinking about physics teaching and physics teachers in this way may provide insights as how to best prepare and support a high-quality workforce.

D. Certification

Darling-Hammond concluded that when assessing several different variables pertaining to teacher quality, teachers' certification status was positively correlated to student achievement [5,23–25]. By understanding the certification status of the physics teaching population, additional insight can be gained regarding the anticipated routes taken by teachers into the profession (i.e., traditional or alternative) as well as the relative teaching experience of the community. Figure 4 indicates that between 85% and 90% of physics teachers have reported a standard certification status over the twenty-five year period between 1987 and 2011, with only minor year-to-year fluctuations. The 10%–15% of physics teachers that reported a nonstandard certification status has shifted, however, between the 1990s and the 2000s. Prior to 2003 (and the No Child Left Behind legislation), up to half of the nonstandard certified physics teachers reported having no certification to teach, but in the last three survey years (2003, 2007, 2011), that proportion has dropped to nearly zero with a concomitant increase in the proportion reporting provisional or emergency credentials instead. In the three most recent survey years (2003, 2007, 2011), additional information (due to a change in the survey questionnaire design) regarding standard-certified physics teachers was available that is important to consider: whether or not the certification was "in field" or "out of field." That is, teachers reported if they were certified to teach a particular subject assigned to them or if they were teaching in an area outside of their licensure. Approximately 50% of the standard-certified teachers were classified as out-of-field physics teachers in every year for which these data were collected.

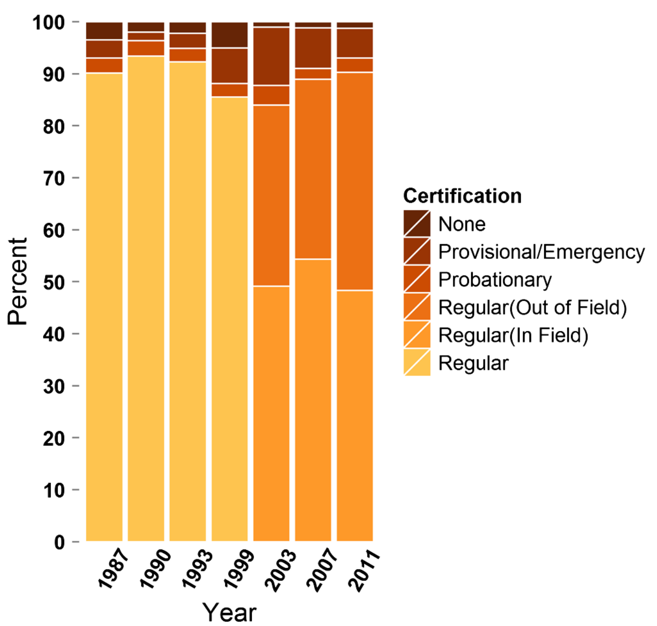

FIG. 4. Proportion of physics teacher with each certification status calculated for each survey year (standard error ≤6.61%).

E. Experience

Henry, Fortner, and Bastian reported that novice teachers specifically in physics, chemistry, physical science, geometry, and biology displayed a greater improvement in effectiveness as they gained years of teaching experience in comparison to non-STEM teachers [26]. By analyzing the trends in experience over time, one can gain additional insight into the potential quality of the workforce, the kinds of teachers that have entered and left over time, and the relative rates of their entrance or departure. AIP has previously categorized teachers by their experience and reported on the relative trends of "specialist" and "occasional" physics teachers, for example [9]. The kernel density plots [27,28] [Fig. 5(a)] show the teaching experience distributions for all U.S. public high school physics teachers (i.e., including both those with physics as a main assignment and those with other primary assignments) at six time points between 1987 and 2011. In 1987, physics teachers were most likely to have more than sixteen years of teaching experience, as the modal peak lies to the right of the dotted vertical reference line (median). The experience distribution is skewed slightly right, but is approximately Gaussian in shape, with approximately equal proportions of less experienced and more experienced teachers on either side of the median of sixteen years. Comparing 1987 to the next two panels from 1990 and 1993, the distribution changes rather dramatically from normal to bimodal, with two distinct maxima at 4.4 and 22.6 years, and a marked decrease of teachers at the fifteen year reference point. The bimodality of the distribution continues into 1999, but with a pronounced increase in the peak for the lower experienced teachers relative to the more experienced group. By 2007, the second relative maximum shifted further towards the right (with a mean >30 years) and decreased again in proportion to the lower experience peak; by 2011 it and is almost unrecognizable as a distinct group. At this last time point, the experience distribution is heavily right skewed with a modal experience at five years and the median value (11.51 years) reaching a minimum from its high of 17.37 in 1990. This distribution shift can be seen more clearly by considering the proportion of those teachers with more than 15 years of teaching experience, compared to those with less, over time [Fig. 5(b)]. The more experienced group has decreased in all six of the most recent survey years, from

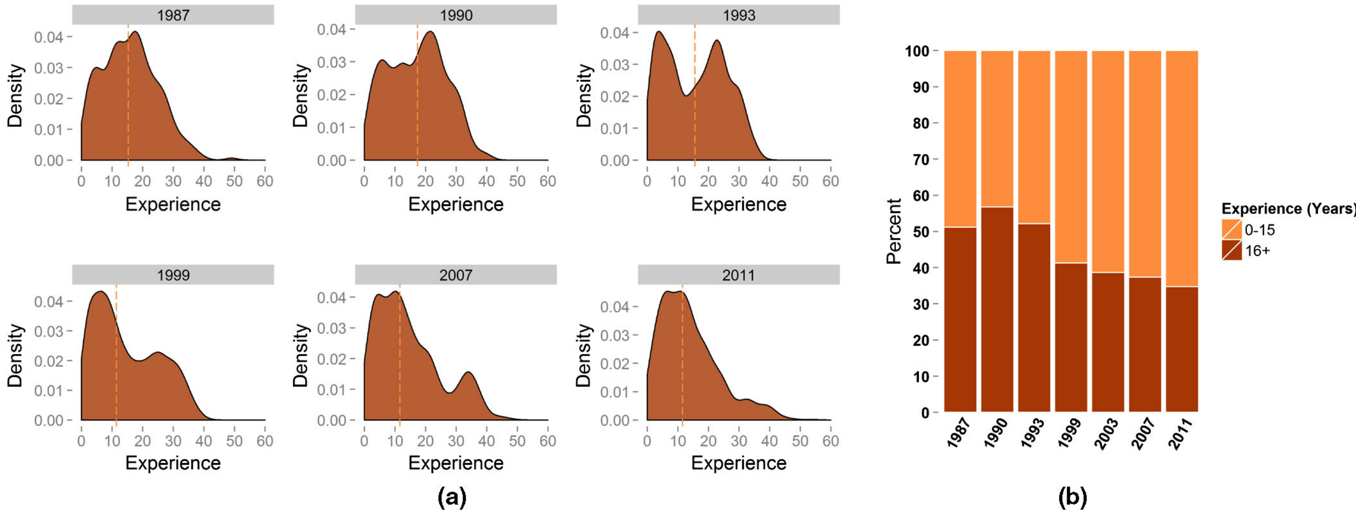

FIG. 5. (a) Kernel density plots for all physics teachers' experience between 1987 and 2011. The reference line in each panel represents the median for that survey year. (b) Percentages of all physics teachers with up to 15 years of teaching experience (orange) compared to those with more than 16 years over the time span studied (standard error ≤4.17%).

a high of nearly 57% in 1990 to less than 35% in 2011. To determine how substantive the changes in experience were over time, we conducted a Kruskal Wallis test and found it to be significant at the 0.01 level ($\mathrm{df} = 6$, chi-squared $= 28.09$, $p < 0.0001$). Although these changes in retention and attrition of the physics teaching population have also been observed in both chemistry [21] and biology [19] as well as the overall U.S. K–12 teaching community [29], physics teachers still remain the most experienced of these comparison groups.

F. Gender and racial diversity

Professional organizations representing the physics community have long recognized the lack of both gender and racial diversity in the physics workforce and have responded with a series of policy statements that strongly encourage members to respond to this need in the recruitment and retention of both women and underrepresented minorities [30]. AIP has recently reported that greater than 90% of all physics teachers in 2008 were white and

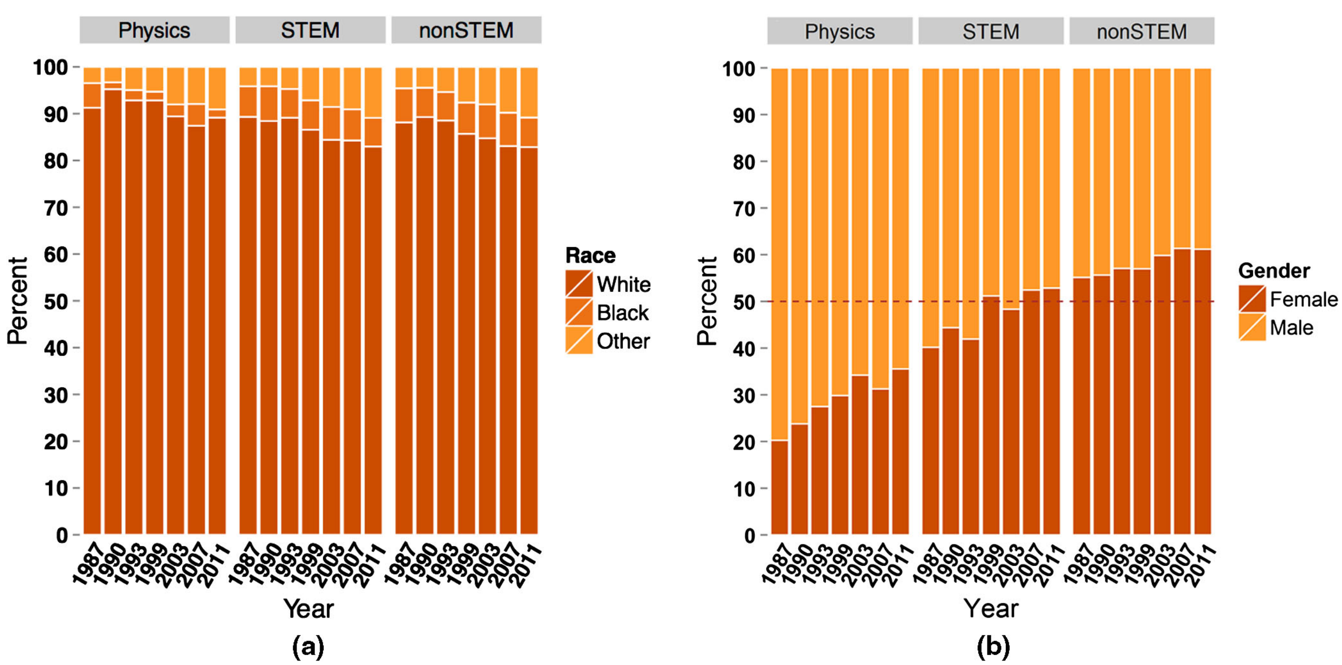

FIG. 6. (a) Racial distribution of physics, STEM, and non-STEM teachers calculated for each survey year (standard error ≤4.3%). (b) Gender distribution of physics, STEM, and non-STEM teachers calculated for each survey year (standard error ≤2.99%).

approximately one-third were women, up from 23% in 1987 [7,9]. Using the SASS as the data set for our analysis, we were able to consider shifts toward racial and gender equity at seven points in a twenty-five year period for physics as well as the secondary STEM and non-STEM teacher communities [Figs. 6(a) and 6(b)]. Though physics teachers have had a historically lower percentage of females, they have approached gender equity at approximately the same rate as the two comparison groups between 1987 and 2011; increasing from about 20% in 1987 to 35% in 2011. Over the same time, high school STEM teachers have achieved near gender equity while non-STEM has slowly approached a 60∶40 female-to-male ratio. Within the major science subdisciplines, physics (65%) has been and remains the most male-dominated compared to chemistry (45%) or biology (40%). Physics lags behind both STEM and non-STEM teachers with regards to racial diversity as well, both overall (i.e., white or nonwhite) and in its proportion of black and other (e.g., Asian) ethnicities. Physics teachers were between 90% and 95% white in the late 1980s and about 2% black; two and a half decades later, they are still almost 90% white and, while more diverse with respect to Asian and Latinos, have not increased the proportion of black teachers appreciably. STEM teachers (excluding physics) and non-STEM teachers are by no means close to being representative of the nation's student population, but have on average more than double the proportion of black teachers and as many or more nonblack minorities as does the physics teaching population [7,31].

VI. DISCUSSION

Taken together, these observations can help to better understand how changes in the physics teacher demographics have coincided with the relative success of physics teacher education reform efforts over the past two decades. Physics classes are being taken by more students and taught by more teachers than ever before, and it has increasingly become a main assignment course. Those teaching physics are increasingly drawn from in-field degrees and are able to teach in-field courses. Relative to chemistry and biology, physics teachers have been more efficiently retained in the profession over time and have more experience. Efforts to diversify the physics workforce and the demographic makeup of the physics teaching workforce are not yet observable, as physics teachers have moved sluggishly toward both racial and gender equity over the past two and a half decades. These findings complement those of AIP by analyzing long-term trends in physics teacher certification status, teaching experience, and racial diversity, as well as details about the main assignments and content background of the out-of-field physics teaching workforce.

Still, there appear to be reasons to reexamine whether or not current efforts are effective enough to achieve the goals of a well-prepared and diverse physics teaching population. Physics teachers are still the most likely of the three core science disciplines to be drawn from outside physics backgrounds, and almost half of the teachers do not teach physics as their main assignment. Those with main assignments in physics are still much more likely than not to have nonphysics degrees and even physics majors are only teaching physics about half of the time. While most physics teachers are certified, only half have certifications in field. Physics teachers are drawn from much more diverse degree backgrounds than other sciences, but are more dominated by white males than chemistry, biology, or STEM overall. Additionally, the field has experienced a loss of experienced teachers over time, although it has retained veteran instructors more effectively than its science peers.

VII. IMPLICATIONS

Our demographic analysis of U.S. public school physics teachers highlights the need to more effectively prepare our physics teaching workforce and minimize the number of underprepared teachers. Considering the history of physics education outlined in the introduction, previous reports from AIP, and the trends discussed in this article, the following considerations may provide a path forward. These considerations complement or reaffirm those suggested by the American Physical Society (APS), the American Association of Physics Teachers (AAPT), and the American Institute of Physics (AIP) [32].

Given that the overwhelming majority of physics teachers are not produced by physics departments, several changes involving universities and professional societies may help produce a higher quality workforce. The emphasis on changing the culture of physics departments at the university level to incorporate physics teacher education into their mission, while laudable and necessary, can only be a part of the solution when the majority of physics teachers are not produced by physics departments [32]. Therefore, physics departments could play a more active role in addressing the needs of this population. Since even out-of-field physics teachers (such as biology or chemistry majors) will have likely taken at least an introductory physics course as part of their undergraduate studies, efforts to improve the quality of these courses might give nonmajors and minors a more meaningful understanding of the content and, ultimately, a better place from which to teach physics. Previous studies have shown that collaborations between physics departments and preservice teachers have been effective at improving the quality of undergraduate physics courses and preparing students for careers in K–12 teaching [33]. Therefore, physics departments could also work more closely with other STEM departments to encourage those going into education to pursue minors in physics, considering that they may be expected to teach this subject in the future. Given that our results show that a significant fraction of the physics teaching workforce have degrees in other STEM fields, this may be a worthwhile collaboration for STEM departments to pursue. Additionally, physics departments themselves may be able to influence state-level decisions regarding accreditation. Since these policies are often impacted by the teacher education and disciplinary communities of each state, departments could help redefine this process by advocating for higher ”passing” scores toward the goal of having high-quality educators in the classroom [32].

The data on the proportion of teachers teaching physics as a main assignment suggests that, for the foreseeable future, a significant percentage of high school physics teachers will not have an exclusive course load in physics. This is especially true for schools located in rural or urban locales, i.e., approximately 50% of the United States [20]. Thus, for many schools, employing a full-time physics teacher who holds a physics major or minor, is certified in their state, and teaches exclusively physics is educationally worthwhile, but simply unrealistic both economically and logistically. Some form of dual or multiple certifications for science teachers could make more sense in these instances, where teachers without an in-field major could demonstrate an appropriate level of content knowledge in their minor subject, and policies for preparing physics teachers should bear this in mind [34].

Given that many physics teachers have limited content background and are often isolated from other physics teachers, the role of professional societies in offering professional development (PD) opportunities is crucial. This geographic barrier to establishing a sound network of physics colleagues [35,36] likely results in a lack of regular interactions with other teachers in the physics community and may require professional societies to make more of an effort to reach out to their constituents instead of expecting physics teachers to come to them. Rather than focusing PD efforts on the minority of physics teachers who have physics backgrounds, efforts might be better directed to the majority of out-of-field teachers who are potentially less likely to attend physics conferences because they identify as nonphysics (i.e., biology, chemistry) teachers. Two specific areas of support might be in content knowledge development and invitation to join a larger community of practice, both locally and nationally [32]. Professional societies such AAPT which have regional sections play a large role in this area, as it may be beneficial to have each region focus their efforts on the teachers that they serve [37]. While these organizations do offer physics professional development opportunities [37], out-of-field or non-main assignment physics teachers may be less likely to attend. AAPT’s Physics Teacher Resource Agent Program (PTRA) as well as the workshops for in-service teachers offered by the University of Colorado and San Diego State University [37] are a few examples of the kinds of efforts that may be quite useful to this population of physics teachers. Therefore, the presence of such professional societies at conferences that may be more regularly attended by out-of-field physics teachers (i.e., biology, chemistry, or math conferences) might be worthwhile in order to cater to those unlikely to attend physics-specific events and make them aware of other opportunities.

Given that our data indicate that the physics workforce is predominantly underprepared, it may be additionally advantageous to concentrate efforts on creating regional centers of physics teacher preparation [32] that would function, for example, much like medical school and ”match” programs [38]. The geographic distribution of medical schools corresponds with areas that have the necessary resources (i.e., hospitals, doctors, training faculty) to sustain these programs and the match program is used to relocate doctors across the nation where needed. Similarly, and in lieu of the present, highly diffused situation with many higher education institutions each producing a small number of teachers (or none at all), efforts might be better focused on supporting universities with larger physics teachers programs and the appropriate resources (e.g., courses on how to teach physics, physics teacher education faculty, qualified local teacher mentors) to produce high-quality teachers, thus alleviating the strain of having multiple low-enrollment programs. These universities could then work in tandem with local groups of physics teachers, which gives preservice teachers a strong base for a professional network. Much like a medical match program, efforts to disperse these highly qualified teachers to schools across the nation might be achieved by surveying teachers and schools nationwide to find compatible pairings.

VIII. CONCLUSIONS

Our analysis of the available demographic data (1987–2012) regarding the composition of the U.S. public school physics teacher workforce allows us to better characterize those teaching physics at the national level. Our findings suggest that while the proportion of physics teachers reporting in-field degrees is increasing, the profession still falls short of having highly qualified physics teachers in America’s classrooms. While experienced teachers have been retained more effectively than other STEM fields, the workforce remains overwhelmingly white-male dominated despite efforts to diversify the race and gender composition of the profession. A better understanding of these attributes should motivate stakeholders to support current physics teachers and advocate for policies and programs that seek to develop a highly qualified, more diverse workforce.

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