RECRUITING TEACHERS IN HIGH-NEEDS STEM FIELDS:

A Survey of Current Majors and Recent STEM Graduates

APS physics

Michael Marder, R Casey Brown, and Monica Plisch,
American Physical Society Panel on Public Affairs

About APS & POPA

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The American Physical Society has sole responsibility for the contents of this report, and the questions, findings, and recommendations within.

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EXECUTIVE SUMMARY

The United States faces persistent shortages of appropriately trained middle and high school STEM teachers in high-needs fields, particularly physics, chemistry, and computer science. The American Physical Society, American Chemical Society, Computing Research Association and Mathematics Teacher Education Partnership surveyed over 6000 current and recent majors in our disciplines.

Our goals were to

- *Investigate the attitudes and opinions of undergraduate majors and recent graduates from high-needs STEM fields towards teaching.*
- *Identify incentives that are both feasible and likely to be effective based on the responses of students showing some interest in teaching.*
- *Develop recommendations for the professional societies and disciplinary departments.*

Our main findings were

- *Around half of STEM majors indicate some interest in teaching, suggesting a significant pool from which more STEM teachers could be recruited.*
- *For STEM majors with some interest in teaching, 80% say that various financial incentives would increase their interest. They report the most powerful incentive would be an increase of teacher salary.*
- *Undergraduate STEM majors underestimate teacher compensation, and the salaries they report would interest them in teaching are close to actual salaries.*
- *Students are most inclined to consider teaching in departments where the faculty discuss teaching as a career option.*
- *Mathematics majors indicate the most interest in teaching and respond most strongly to incentives. Chemistry and physics majors show less interest and physics majors respond less strongly to incentives. Computer science majors show the least interest.*
- *The aspects of teaching that most worry STEM undergraduates are substantially different from the aspects of teaching that worry practicing teachers.*

Our recommendations to professional societies and disciplinary departments are to

- *Impress upon university faculty and advisors in STEM disciplinary departments the importance of promoting middle and high school teaching with their undergraduate majors and graduate students, and of providing them accurate information about the actual salary and positive features of teaching.*

- *Support high-quality academic programs that prepare students for STEM teaching, and expand good models to more universities. Strong programs provide improved coursework, prevent certification from requiring extra time, and support their students and graduates financially and academically.*

- *Support financial and other support for students pursuing STEM teaching.*

- *Advocate for increases in annual compensation, including summer stipends, on the order of $5K-$25K for teachers in the hardest to staff STEM disciplines.*

- *Support programs that improve the professional life and community of STEM teachers.*

Introduction

The United States has been one of the world leaders in technological innovation throughout most of the 20th and 21st centuries. It is where John Bardeen's understanding of surface physics created the first transistor, where Jack Kilby and Robert Noyce invented the first integrated circuits, where Irving Langmuir founded surface chemistry which underlies integrated circuit manufacture, and where Claude Shannon developed the mathematical theory of communication, including the concept of the 'bit'. Since the conclusion of World War II, researchers working in the United States have won more Nobel prizes for physiology or medicine, chemistry, physics, biology, and economics than those in any other country (Bruner, 2011).

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Science, technology, engineering, and mathematics (STEM) drives much of the innovation in business and industry. For every extraordinarily successful business such as Microsoft, there are thousands of successes on smaller scales. As one example, after thirty years working at various software firms, Richard Sheridan founded in 2001, Menlo Innovations, a software technology company with three partners. In 2014, the company had grown to approximately 50 people and *Inc. Magazine* listed it as one of the 5,000 fastest growing private companies in America.

Even for those who do not win a Nobel Prize or found a company, a degree in STEM has many advantages. Companies as varied as Apple, ExxonMobil, and Boeing rely on employees with technical talent to provide world-leading products and services. Careers in STEM-related disciplines are expected to be some of the best paid and fastest growing in the coming decades (BLS, 2014). The opportunities for employment in STEM fields are real, although there are also STEM subfields where the number of people seeking work is larger than the number of positions (BLS, 2015).

In order to meet projected demand for STEM professionals and ensure America remains competitive in science and technology, it is imperative that students be adequately prepared for careers in these disciplines. Today a large fraction of the US technical elite has been born and educated up through college abroad.

For example, nearly half of PhD aerospace engineers, over 65% of PhD computer scientists, and nearly 80% of PhD industrial and manufacturing engineers were born abroad (NSCG, 2015). Valerie Giscard d'Estaing famously referred to the United States' "exorbitant privilege" in controlling the world's reserve currency, but the advantage from attracting many of the world's best educated technical minds is just as great. Foreign enrollment in US graduate STEM programs continues to rise (CGS, 2015), but this pattern is unlikely to persist undiminished into the future. Thus we must improve the odds that our own citizens will be motivated and well prepared to pursue post-secondary training in the STEM disciplines.

"I never had a chance to take any CS courses until college. When I got here, I felt like I was already pretty far behind everyone else."

– US computer science undergraduate

Despite the promise of a rewarding career, there is still a shortage of US citizens with the requisite training to fill STEM jobs. Many high school seniors interested in majoring in a STEM field are underprepared and unable to handle the rigorous courses required. In one study, only 26% of high school seniors who expressed interest in STEM majors met a benchmark showing them prepared to be successful in a rigorous STEM discipline (ACT, 2015). When these results are broken down by race and ethnicity, 49% of Asian students, 13% of Hispanic students, 32% of white students, and 5% of black students met the benchmark. The results of meeting this STEM benchmark are significant. ACT researchers found that, of those who met the STEM mathematics benchmark, 49% went on to earn a STEM degree within six years, while only 23% of those who did not meet the benchmark went on to earn a STEM degree. For the STEM science benchmark, 42% of those meeting the criteria earned a STEM related bachelor's degree within six years, compared to 22% for those students who did not meet the benchmark.

One possible reason students do not complete STEM degrees is that exposure to STEM disciplines is limited during high school, particularly in comparison with elsewhere in the world. As an example, four or five years of physics is common in Europe and China (Bao et al, 2009); however, in the United States, approximately 40% of students will take as much as one year (American Institute of Physics, 2014a), and only a third of their teachers have a physics or physics education major (American Institute of Physics, 2014b).

Default offering of one year of physics, chemistry, and computer science for all high school students seems prudent in light of the importance of STEM fields for the future of the United States. However, the shortage of qualified teachers presents a severe barrier. Physics is not alone in finding that high school course offerings are limited by the availability of teachers who are fully certified to teach and have a major or minor in the discipline. Chemistry has shortages similar to physics. Computer Sciences, Engineering, and Earth and Space Sciences face even worse shortages and have correspondingly smaller course offerings. An indication of these shortages is provided in Table 1, which shows that although the United States has a much smaller fraction of its students taking courses in physical sciences than students in other countries, our teachers lack basic qualifications more than half the time. Meeting these qualifications is important in order to engage and challenge students in the content, and maximize learning. It is imperative that the teacher have a mastery of the material and know how to teach it.

TABLE 1
Teachers out of field or without full certification for selected disciplines. (Schools and Staffing Survey, 2012)

Subject	Number of Teachers	Percent with no major or minor in main assignment or not certified
Math	144800	38%
Science	126,300	27%
Biology	51,900	35%
Physical Science	64,600	62%
Chemistry	24,300	66%
Earth Sciences	12,400	68%
Physics	13,300	63%

In formulating a study of how to address STEM teacher shortages, the American Physical Society worked with three other professional societies: the American Chemical Society, the Computing Research Association, and the Mathematics Teacher Education Partnership. The shortage of teachers is particularly troublesome in the field of computer science as 70% of new STEM jobs in the future are expected to be in fields such as software developer, information systems analyst, software engineer, and computer networker. Yet only around 25% of US high schools even offer computer science in any capacity (Dickey, Feb 24, 2016) and only about 10% offer courses that prepare students for the AP computer science exam (Guzdial, 2012).

In addition to threatening the ability of the United States to remain competitive on the global stage, the shortage of qualified STEM teachers perpetuates gaps in academic achievement and subsequent professional success between those from higher socioeconomic backgrounds and those from lower socioeconomic backgrounds. The most qualified teachers are typically hired by affluent suburban districts, while poorer urban and rural districts may resort to hiring underqualified STEM teachers, or none at all (Aragon, 2016; Mader, 2014; Ossola, 2014). Increasing the supply of qualified STEM teachers should increase access, spawn interest in capable students across the SES spectrum, and in turn lead to a greater number of those pursuing STEM at the post-secondary level.

This state of affairs has not gone unnoticed. In the 2011 State of the Union address, President Barack Obama outlined a plan to prepare 100,000 new STEM teachers by 2020 (Obama, 2011). This was part of an effort to ensure the United States benefits from the capabilities of all its people. Several organizations have emerged to coordinate the national effort, such as 100Kin10, Change the Equation, and the National Math and Science Initiative. There are numerous national programs with the goal to increase physics and other STEM teachers in the United States. We mention a few. PhysTEC is a program run by the APS in partnership with the American Association of Physics Teachers (AAPT) and funded by the National Science Foundation (NSF) and donations to APS. It specifically targets preparation of physics teachers at selected universities. Noyce Scholarships provide NSF funding for students who commit to teach STEM subjects in high-needs Local Educational Agencies (districts). UTeach uses a mixture of private and public funding to create teacher preparation programs and increase the number of STEM teachers at selected universities. Even when all three of these programs operate simultaneously at a university, the numbers of physics, chemistry, and computer science teachers produced remains modest, rarely exceeding 5-10 in each category per year. Thus the national gains have remained small in relation to the national need.

We refer in this report to high-needs STEM fields. By this we mean STEM disciplines where it is particularly difficult for high schools to find qualified teachers: physics, chemistry, computer science, engineering, and earth sciences. The shortages in biology and mathematics are less. However, we include mathematics in our survey because we want to have a point of comparison with a discipline that seems similar to the others, particularly physics, yet the tradition of preparing teachers is stronger, and the resulting shortages less.

Objective of Study

We surveyed undergraduate STEM majors and recent STEM graduates with the goal of identifying specific measures to recruit more of them to become STEM teachers. The analysis has three primary objectives.

- *Investigate the attitudes and opinions of undergraduate majors and recent graduates from high-needs STEM fields towards teaching.* Among the undergraduates, a population of particular interest is those who could be persuaded to teach. The graduates include practicing teachers, and their responses provide valuable information about the attractiveness of the profession.

- *Identify incentives that are both feasible and likely to be effective based on the responses of students showing some interest in teaching.* Through tailoring incentives and other initiatives to this group of students that are both qualified to teach and interested in doing so, maximize efficiency by targeting resources to those more likely to teach.

- *Develop recommendations for the professional societies and disciplinary departments.* The encouragement and support students receive to enter teaching depends greatly upon discipline and institution, and the professional societies can address STEM teacher shortages by helping members at educational institutions adopt best practices.

Survey

The survey on which this report is based was designed in the fall of 2015 and administered in the fall of 2015 and spring of 2016. The survey respondents were obtained from contact lists, and existing national survey initiatives of the American Physical Society (APS), American Chemical Society (ACS), Computing Research Association (CRA), and the Mathematics Teacher Education Partnership (MTEP).

The CRA is home to a research and evaluation center called the Center for Evaluating The Research Pipeline (CERP). CERP has assembled a collection of computing departments called "Data Buddies" intended to provide a representative sample of institutions throughout the United States; buddy departments distribute CERP's semi-annual surveys to students in their department. During the year of the survey described here, 97 colleges and universities were active in the Data Buddies Project.[1] CERP added the survey questions described in this report to its existing semi-annual surveys: one in spring 2015 directed at seniors in CS about to graduate, and one in fall 2015 directed at students majoring or minoring in CS, or enrolled in CS courses. The remainder of the survey results was collected by the American Institute of Physics using contact lists from three sources. The first of these was a list of members of the American Physical Society who were current undergraduates or had graduated in the past three years. The second was a list of graduates of PhysTEC programs. The third was a list of current undergraduates and recent graduates from the American Chemical Society. Finally, with assistance from the Mathematics Teacher Education Partnership we obtained the ability to send students links to the survey through their math departments at many of the universities that are members of the partnership.

The computer science sample is both the largest and the most representative in terms of systematic coverage of geographic region and institution type. The samples from the American Physical Society and American Chemical Society are similar in that they are drawn from national membership in professional or-

1 To learn more about the Data Buddies Project, visit http://cra.org/cerp/data-buddies/

ganizations. However, they are not necessarily representative of what one would find in a random sampling of physics and chemistry majors. For example, the American Physical Society has made a concerted effort to encourage female physics majors to apply; perhaps this is why 40% of both the undergraduate and post-baccalaureate physics sample is female, while only 20% of undergraduate degrees in physics go to women (AIP 2012). This over-representation of women is not however confined to the physics sample. Thirty percent of the Computer Science respondents were female, whereas national statistics indicate that fewer than 20% of CS undergraduates are women, and 58% of the respondents in chemistry were female whereas 50% of undergraduate degrees go to women in chemistry (IPEDS 2014).

The numbers of completed surveys coming from these survey channels is indicated in Table 2, and the distribution of majors appears in Table 3. Nearly 40% of physics majors and 30% of math majors had double majors; we used the major they listed as their first or primary major.

TABLE 2
Completed surveys by contributing organization. Surveys where respondent indicated no interest in working in US are excluded.

Group	Completed Surveys
American Physical Society	1393
PhysTEC	64
Computing Research Association	3997
American Chemical Society	1321
Mathematics Teacher Education Partnership	1122
TOTAL	**7897**

The main caution we must offer about the respondents to the survey is that the sample is probably biased towards individuals with a propensity to teach. This is least likely to be true for the computer science students, who were taking it as part of a larger survey effort where attitudes about teaching were only part of the focus, and most likely to be true of the mathematics students, since the whole sample was made available by faculty engaged in the Mathematics Teacher Education Partnership. An additional observation on the mathematics sample is that it contained large numbers of responses from a relatively small number of institutions; in one case 179 mathematics students responded from one university, while the largest number of chemistry students to respond from any given university was 17, and for physics the largest response from a single campus was 20. Any results we report for mathematics must therefore be regarded with caution, but we note that the institutions providing the largest numbers of responses are large public research universities with strong programs in pure mathematics, rather than smaller institutions that focus primarily on mathematics teacher preparation.

Major	Under-graduates	Degree Holders	Total
Physics	575	628	1203
Chemistry	633	332	965
Mathematics	932	76	1008
Computer Science	3616	4	3620
Engineering	202	75	277
Other	223	36	259

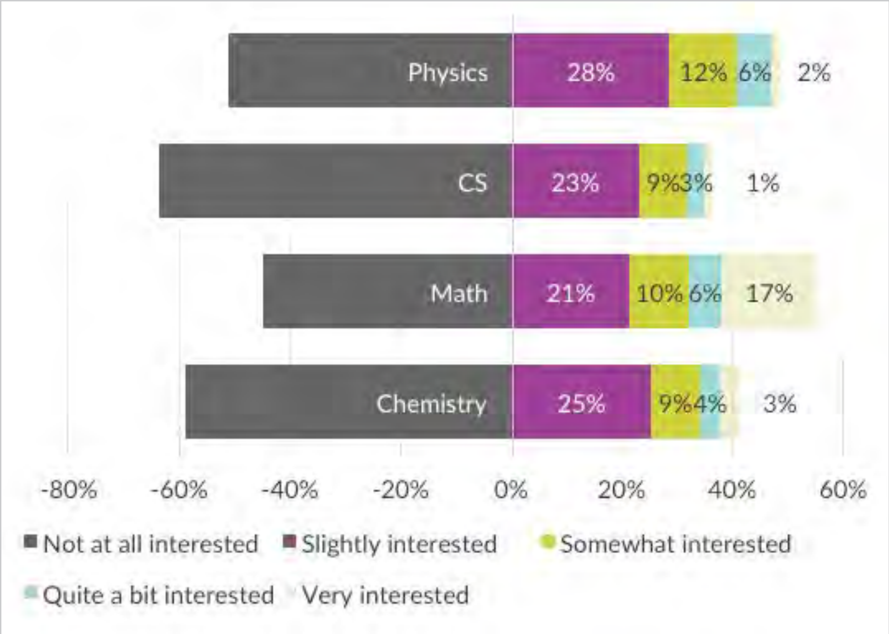
TABLE 3
Numbers of majors in sample, grouped by graduation status.

Attitudes and Opinions Concerning Teaching

Interest in Teaching

As shown in Figure 1, approximately half of all undergraduates in our sample say that they are not all interested in teaching, a quarter exhibit mild interest, and the remaining quarter are somewhat, quite a bit, or very interested. The lowest degree of interest is among the CS students and the highest among math. The number of math students saying they are very interested in teaching is nearly 20%, which is ten times as high as for the other disciplines. Physics and chemistry have results nearly identical to each other. The number of CS undergraduates who say they are very interested in teaching is particularly small; only 1%, and adding together Quite, and Very interested gives only 4%, which is half the fraction for chemistry or physics. For degree holders in physics and chemistry, the response to the question is nearly identical as it is for undergraduates; in math and CS the degree-holder population is too small to report the results.

FIGURE 1
Undergraduates respond to the question "How interested are you in being a middle or high school teacher?"



Appealing Features of Teaching and Worries About Teaching

The survey included an opportunity for students to respond to open-ended prompts about the appealing features and worries they associated with teaching. We coded the responses and display appeals of middle and high school teaching in Figure 2, and concerns about teaching in Figure 3.

There is more variety in the description of the appeals of teaching than there is in the concerns. Appealing features include the possibility of mentoring the next generation, the attraction of working with kids, certain aspects of the job, the prospect of autonomy. Nearly 1 in 8 respondents mentioned sharing enthusiasm for technology with the next generation. Many liked the idea of having summers off.

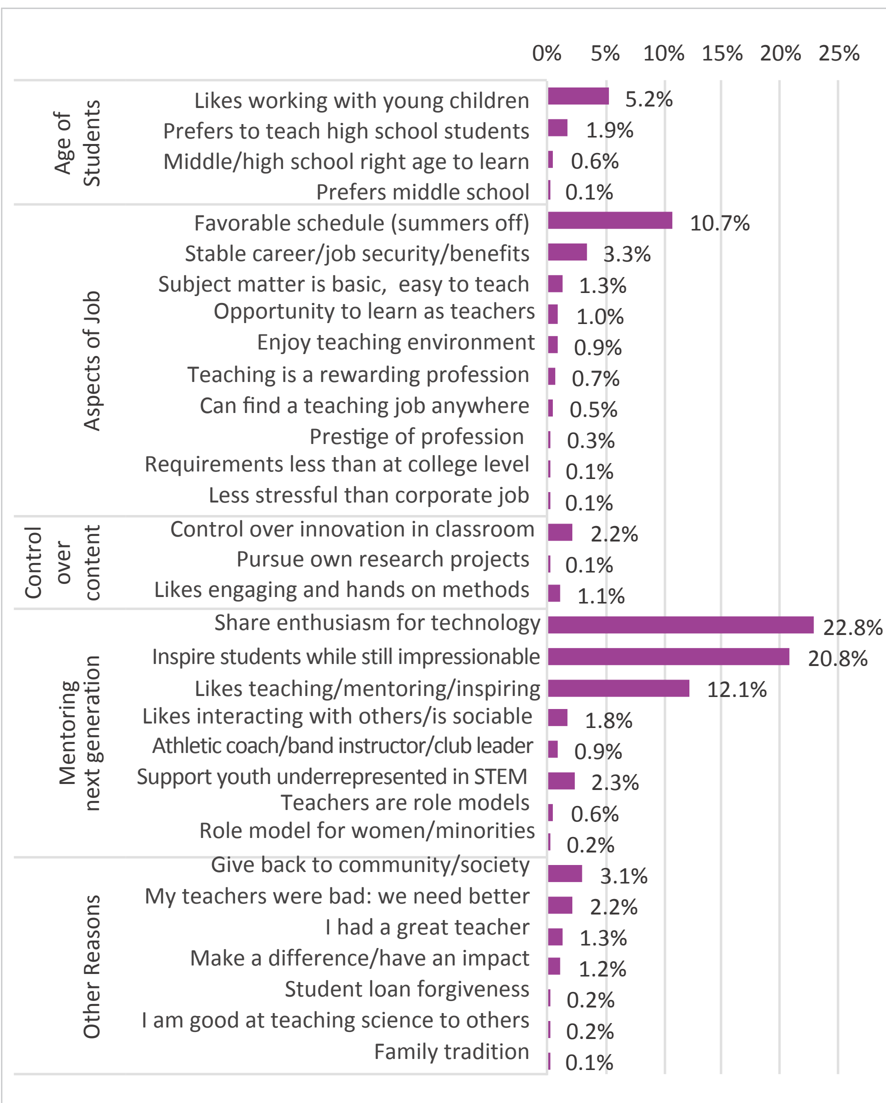


FIGURE 2

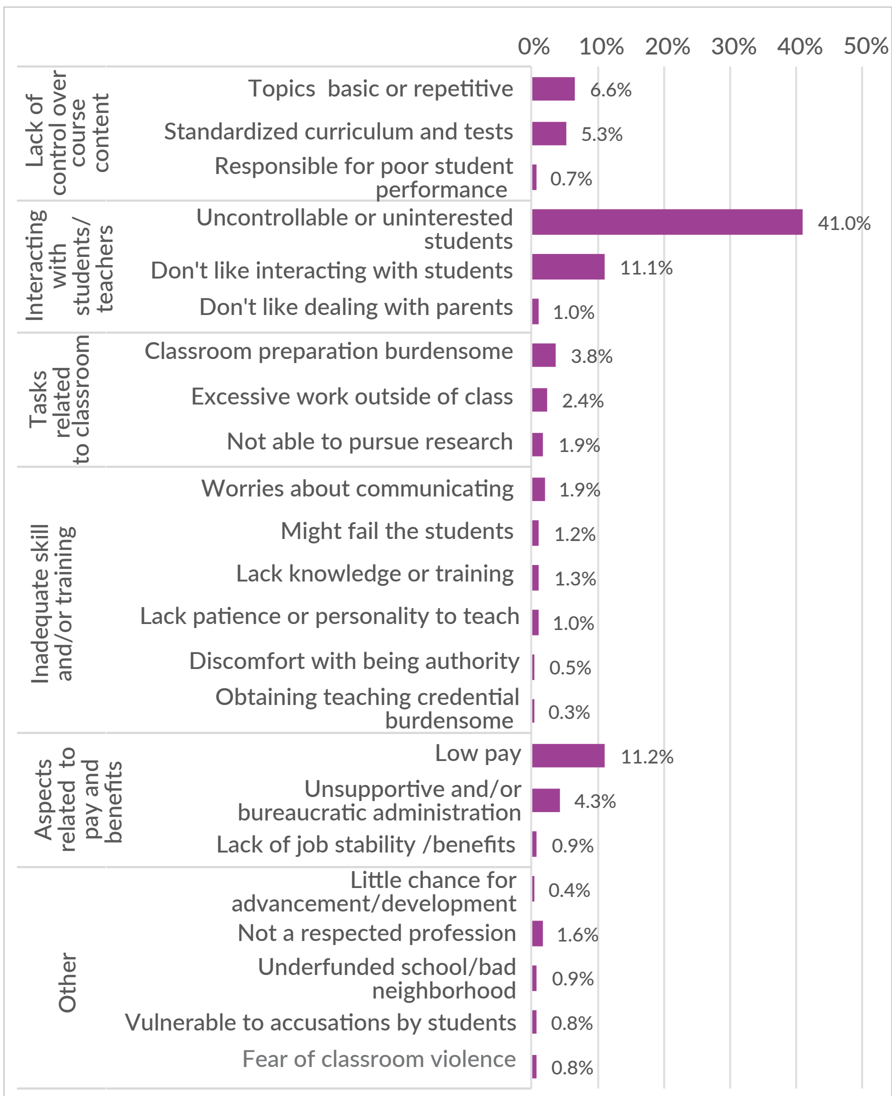
Respondents provided open-ended descriptions of things that would appeal to them about being a middle or high school teacher.

The main concern about teaching is the worry of dealing with disrespectful, uncontrollable, or uninterested students. This concern showed up four times as often as the next-largest concern, which was low pay. Nearly tied with low pay were dislike for working with kids, and worries about lack of control over curriculum.

Even respondents who said they had no desire at all to enter teaching often responded to the prompt for appealing features of teaching with remarks about inspiring the next generation, although many left the item blank. However, among the CS students there was a noticeable fraction who said that what appealed to them about teaching was "Absolutely nothing." There was a distinct difference between majors for this response. About 6-7% of physics, chemistry, and math majors responded in this manner, compared with 19% of CS majors.

FIGURE 3

Respondents provided open-ended descriptions of things that would worry them about being a middle or high school teacher.



Teacher Salaries and Perceptions About Teacher Salaries

In a 2015 Huffington Post/YouGov poll, of Americans, just over half of respondents felt public school teachers were underpaid (Klein, May 4, 2015). This opinion may or may not be based on accurate knowledge of what teachers make. According to the Bureau of Labor Statistics (2015a) the average salary for a U.S. middle school teacher in 2015 was $58,760 and $60,270 for a high school teacher. The salary is heavily dependent on location and longevity. Teacher salary tends to be higher in metropolitan areas. Figure 4 provides salary data for metro and non-metro locations from eight states representing different regions of the United States. Lower salary is only one of the reasons that supplying qualified teachers for non-metropolitan areas poses special challenges. STEM teachers in rural areas can be responsible for teaching many different subjects, and find themselves a long distance from any professional support networks.

It is important to emphasize here and elsewhere in this report that teacher salaries are reported as base salaries for the regular school year, without taking into account additional compensation from summer employment, school leadership, or other activities. Teachers frequently increase their annual compensation by assuming duties such as department chair, coaching, conducting professional development for other teachers, teaching summer school, or taking non-teaching summer jobs. Thus total annual compensation for teachers is not necessarily as far below that of other STEM professions as it might first appear.

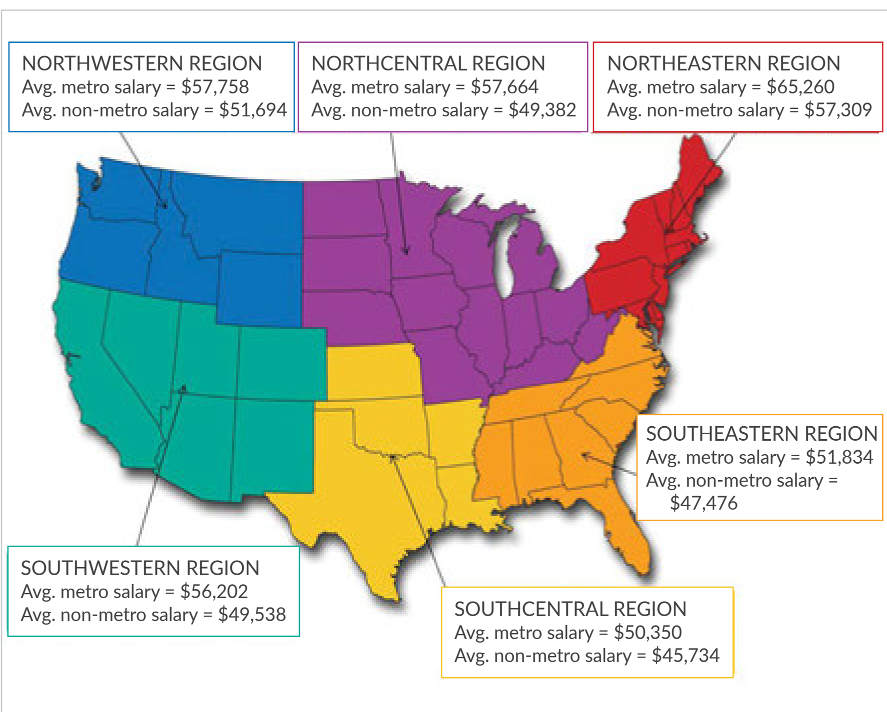


FIGURE 4
Average high school teacher salary by region. (Bureau of Labor Statistics, 2015a)

Figure 5 provides the mean salaries for STEM fields and middle and high school teaching. STEM workers earned, on average, anywhere from $10,000 to $20,000 more than middle and high school teachers and this difference has remained fairly constant from 2005 until 2014. Salary increases for math, computer sciences, architecture, and engineering have continually outpaced the increases for teachers.

FIGURE 5

Mean salary by job category for a variety of STEM-related careers. (2005-2014, Bureau of Labor Statistics, 2015a)

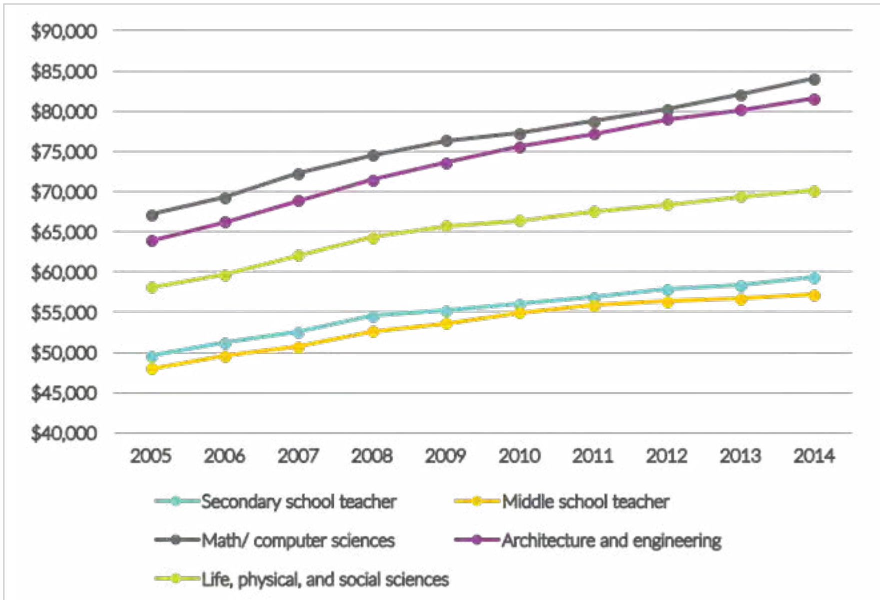
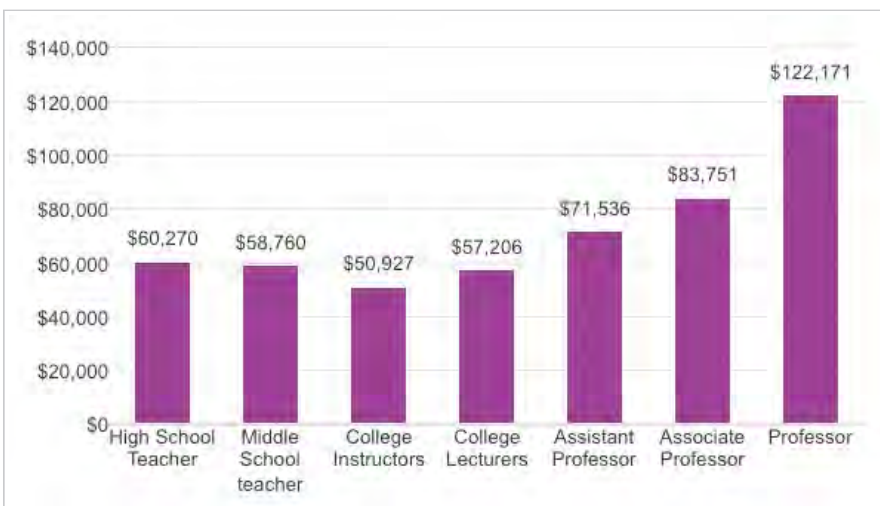


FIGURE 6

Average salaries for a number of different teaching professions in 2014-2015. (American Association University Professors, 2015 and Bureau of Labor Statistics, 2015a)



While high school teaching therefore lags behind other STEM fields in terms of salary, for students with an interest in teaching, the comparison of salary levels in Figure 6 may be instructive. The salaries of high school and middle school teachers are less than those of tenure/tenure-track college faculty. However, they are greater than the salaries of college instructors and lecturers. While, historically, tenured faculty have outnumbered non-tenured faculty, that trend has reversed in the last few decades as in 2009, nearly two-thirds of all academic positions at U.S. institutions were staffed by non-tenured faculty, compared to approximately 22% in 1969 (Kezar and Maxey, 2012).

Perceived Salary

We asked our respondents to tell us how much they think the average middle or high school teacher makes during a 9-month school year in their current location. For example, for a student living in Texas, the value for actual teacher salary would be $52,420. In Figure 7, we compare the results with the actual mean teacher salaries in their states. Respondents perceived teacher salary to be almost $17,000 less than actual teacher salary. None of the individual majors gave responses that were appreciably different from the average over majors.

FIGURE 7

Perceived and actual teacher salaries. Green line shows salary perceived by respondents, while purple bars show actual mean salaries in respondents' states. (Bureau of Labor Statistics, 2015a)

Starting Salary

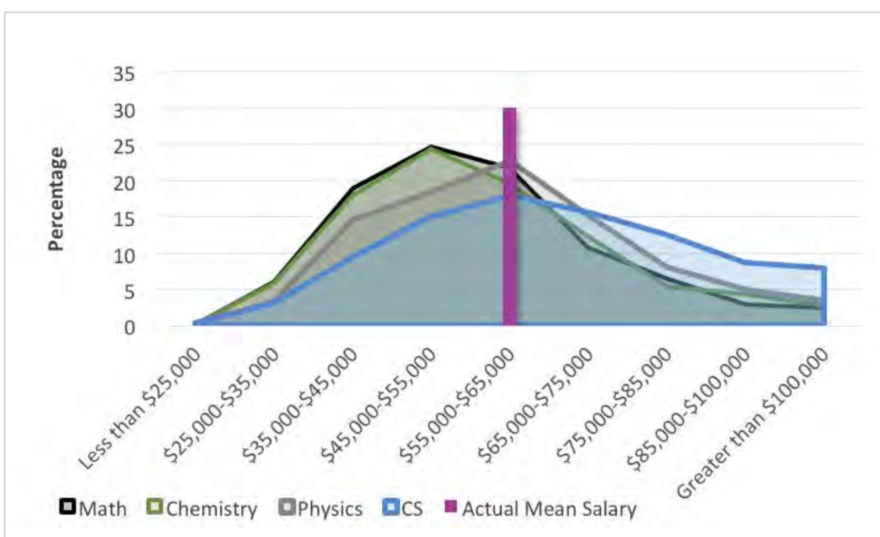
Next we asked the respondents to indicate the salary they would request as an entry level middle or high school teacher. For comparison purposes, these requested starting salaries were plotted against estimated actual starting salaries for high school teachers in 2015. These estimated starting salaries were obtained by taking the average starting salary for each state for the 2012-2013 school year (NEA, 2013) and adjusting for 2014-2015 assuming a 2% annual increase. Those results are presented in Figure 8. Mean requested starting salaries were slightly below actual starting salaries.

FIGURE 8
Desired and Actual Starting Salary. (NEA, 2013)

Finally, we asked what salaries would be desired after five years, as respresented in Figure 9. In physics, chemistry, and math the mean desired salaries were within $1000 of the actual annual salaries. In computer science, the actual mean salary was $61,000/year, while the mean desired salary was $66,000/year.

It is one thing for a student to speculate about desired salaries five years in the future, and something else to enter or remain in a profession when presented with actual job offers and the ability to check competing pay scales. Nevertheless, it is striking that students consistently underestimate what teachers actually earn, and when asked what they would want to earn as teachers, students indicate a desired salary very close to the current actual salary. Only in the case of computer science do students express an interest in higher salaries than the market is currently providing.

FIGURE 9
Desired salary after 5 years' service compared by major with actual mean salary. (Bureau of Labor Statistics, 2015a)



Incentives to Teach

Respondents were asked about six different strategies intended to recruit them into teaching, described to them as

1. "Access to high-quality courses at my institution that prepared me to be a successful teacher."

2. "All my student loans could be forgiven if I were to teach for 5 years."

3. "Better teaching salary."

4. "I would not have to spend extra time in school to obtain a teaching certificate."

5. "I would be given free tuition for extra time spent obtaining my teaching certificate."

6. "There are currently scholarships available for people in science and math teaching certification programs. Scholarships up to $20,000/year are awarded on the condition that, after earning a certificate, one teaches two years in high-needs areas for each year of financial support."

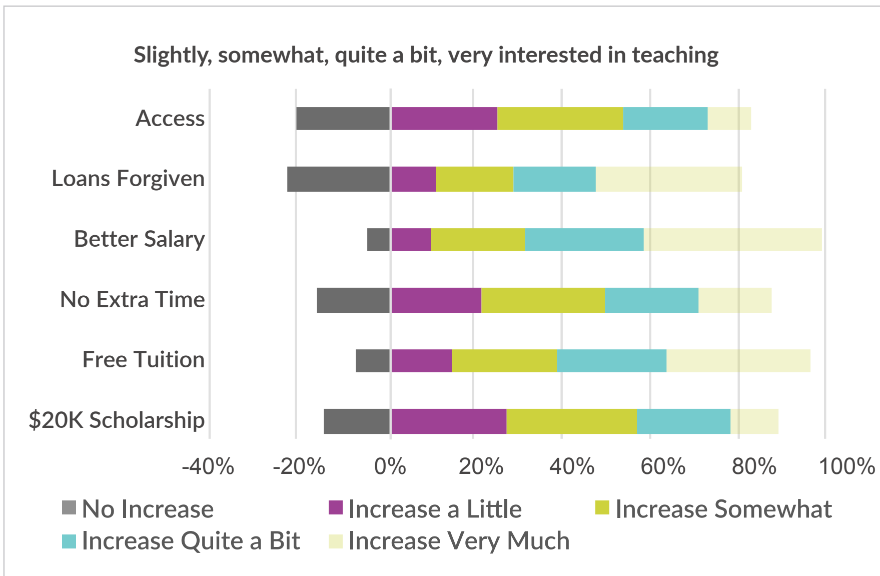
Incentives 1 and 4 correspond to program improvement, of the sort promoted by PhysTEC and UTeach. Incentives 2, 5, and 6 are financial incentives delivered to candidates while they are preparing to be teachers. Incentive 6 in particular is modeled on the National Science Foundation Noyce program. Incentive 3 returns to the question of teaching salary.

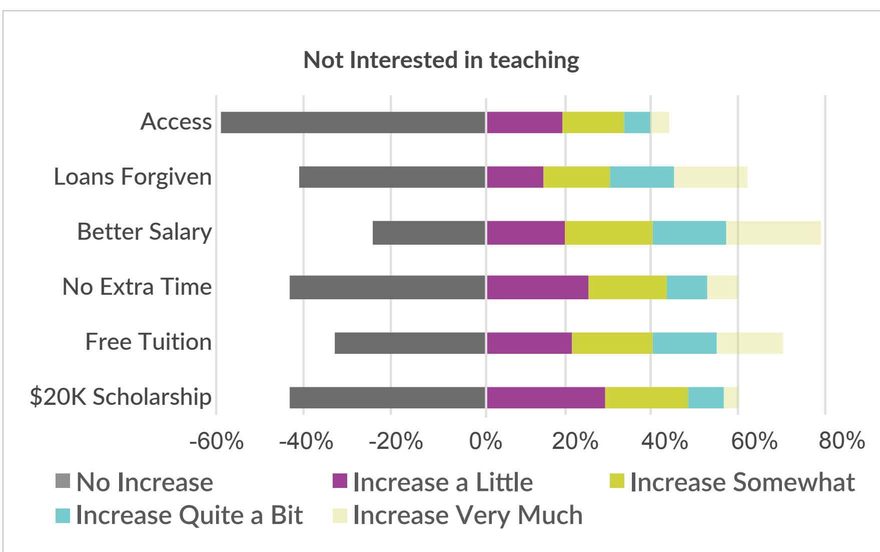
Probing students with questions of this type can be problematic. For example, students not actually enrolled in an academic program may not fully appreciate the effect it would have upon them if, upon starting, they learned it would require an extra year of tuition payments. Nevertheless, the student responses to the different recruitment and support strategies are instructive, particularly if one focuses on comparing reactions to the different incentives.

In Figure 10, responses are broken out according to whether the students had indicated some or no interest in teaching. For respondents who initially indicated no interest in teaching, around half indicated that the recruitment strategies would increase their interest. Of the program improvement strategies, the promise that they would not have to spend extra time in school to obtain a teaching certificate was of more interest than having access to high-quality coursework. Loan forgiveness, free tuition for teaching courses, and the $20K scholarship were of roughly equal in having students express some interest in teaching, but the loan forgiveness and free tuition spurred a considerably higher percentage (over 20%) to say that the programs would increase quite a bit or very much their interest in teaching.

FIGURE 10

Reactions to six strategies currently used to attract individuals into STEM teaching. The upper panel is restricted to respondents who indicated some interest in teaching, while the lower panel is restricted to those who indicated none.





For respondents who initially indicated some interest in teaching, 80% or more indicated that these incentives would increase their interest. Free tuition and loan forgiveness, said 30% of them, would increase their interest in teaching very much.

Whether for those with or without initial interest in teaching, the most popular recruitment strategy was an increase in teaching salary. Nearly 40% of those with some initial interest in teaching said it would increase their interest very much, while for those not indicating initial interest, 20% said it would increase their interest very much.

To what extent did the six incentives affect majors differently? This was examined using ordinal logistic regression.[1] Since mathematics students are the most likely to enter teaching, their responses to the various incentives were used as a baseline major while controlling for gender, ethnicity, and interest in teaching. The results were that the responses of chemistry students could not in any case be distinguished from the responses of math students. The responses of physics and computer science students were however significantly less positive than those of the math and chemistry students, as shown in Table 4. For example, physics students were only .54 times as likely to respond favorably to free tuition as mathematics students.

TABLE 4
Odds that physics or chemistry students would respond favorably to incentives compared with mathematics students. The physics and chemistry students are from 0.8 to 0.47 times as likely to respond to the incentives. All results significant with |t|>2.5.

	Access	Loans Forgiven	Better Salary	No Extra Time	Free Tuition	20K Scholarship
Physics	0.65	0.6	0.68	0.71	0.54	0.64
Chemistry	0.71	0.47	0.69	0.8	0.62	0.67

Thus each of the strategies we examined to attract students into STEM teaching was effective at increasing the interest of students, whether they were initially interested in teaching or not. For students who displayed some interest in teaching, each strategy caused around 80% of them to become more interested. Loan forgiveness and tuition support for courses leading to certification are the financial support strategies that interested students the most. Neither program improvement nor student financial support increased student interest as much as the prospect of increased teacher salary.

1 In ordinal regression, the proportional odds ratio is interpreted in much the same way as the odds ratio in basic logistic regression.

Graduate Job Satisfaction

Among the 1161 graduates or degree holders in our sample, most within three years of graduation, were 109 teachers. We compared the teachers' job satisfaction with that of the other graduates as shown in Table 5. We gathered responses asking for satisfaction on a five-point scale ranging from very dissatisfied to very satisfied and we report the probability of middle and high school teachers reporting satisfaction in comparison with others.[1] In five cases, the difference in satisfaction with particular job features proved to be statistically significant. The teachers were half as likely to express satisfaction with salary, two-thirds as likely to say they had opportunities for advancement, nearly twice as likely to say their job was secure, half as likely to say their job was prestigious, and six times as likely to say their current job made a difference in other peoples' lives.

TABLE 5
Teachers' satisfaction with job features in comparison with other recent graduates. They are less than half as satisfied with salary and nearly six times as satisfied with ability to make a difference in others' lives. Responses marked with * indicate statistically significant difference.

Job Feature	Odds Ratio	t
Salary	0.46	-3.96*
Benefits	1.14	0.69
The level of intellectual challenge	0.95	-0.28
The level of responsibility.	1.11	0.54
Opportunities for advancement.	0.65	-2.24*
Job security	1.78	2.91*
The level of prestige associated with your job.	0.45	-4.00*
Your ability to make a difference in people's lives through your current job.	5.99	7.92*

1 We performed a probit regression using the routine *polr* in R.

The teachers also responded to the same set of open-ended prompts about the most and least enjoyable aspects of being a teacher. These results are presented in Figures 11 and 12. For enjoyable aspects of teaching, teachers and non-teachers settled on similar themes. Mentoring students and making a difference in other peoples' lives was the most common response. For the least enjoyable aspects of teaching there were interesting differences. While non-teachers overwhelmingly singled out worries about uninterested, misbehaving students, this problem was not at the top of the list of actual teachers. The teachers were more concerned about hostile or nonresponsive school administration and excessive non-teaching activities.

Our sample of graduates included 388 who were neither teaching K-12 nor in graduate school, almost all of them from physics and chemistry majors. We compare the starting salaries they reported with the starting salaries of the teachers in Figure 13. We observe that the most frequently reported salary for those not teaching was below $25,000. More than 10% did not yet have a job, although that is mainly because most of these graduates had only completed their degree within the past year. Even after excluding them, however, 64% earned $45K or less, meaning they earned no more than the beginning teachers.

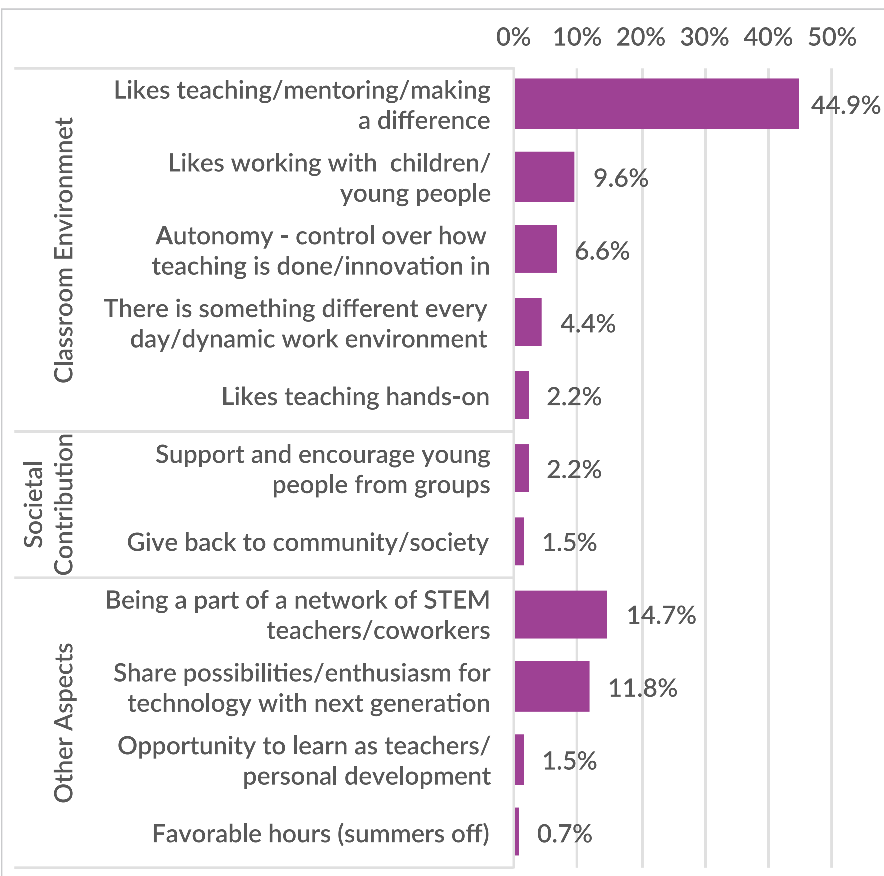


FIGURE 11

Respondents who are teachers provided open-ended descriptions of things that they like most about being a middle or high school teacher.

FIGURE 12

Respondents who are teachers provided open-ended descriptions of things that they like least about being a middle or high school teacher.

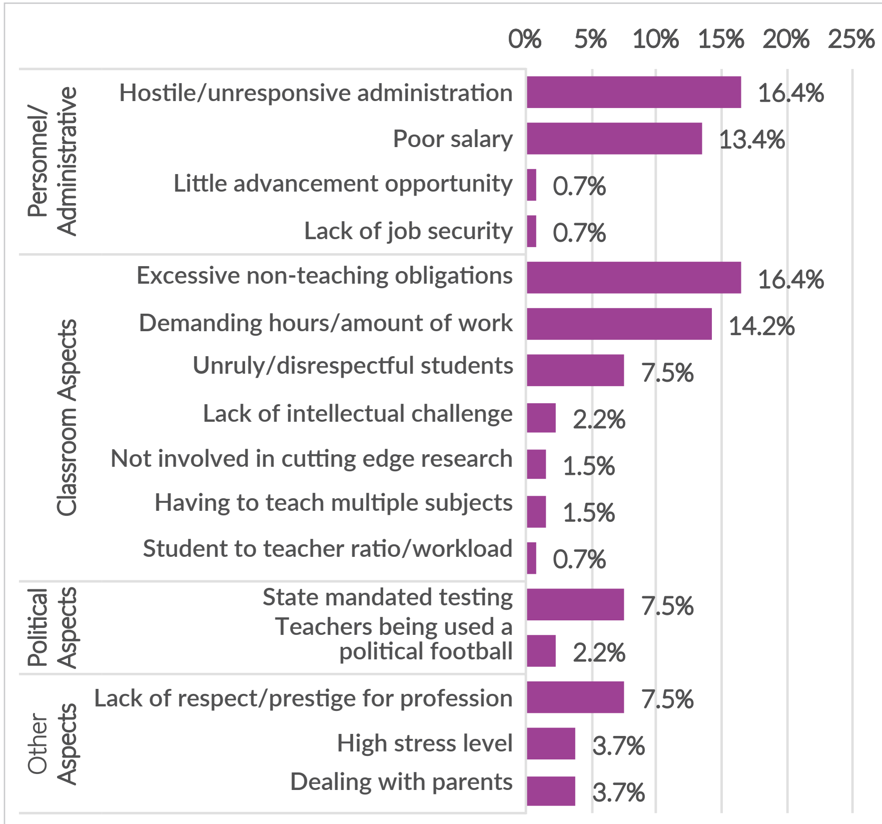
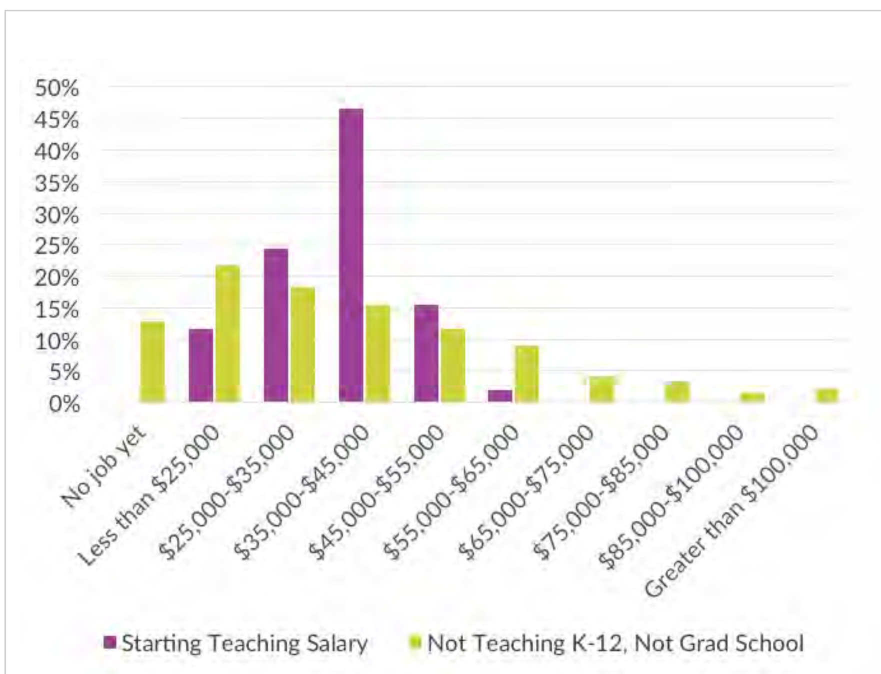


FIGURE 13

Starting base 9-month salary of middle and high school teachers compared with starting salary of other recent graduates. Graduate students removed.



Support from Academic Institutions

Students indicating some interest in teaching were asked a number of questions about support from their major department. Only around 30% of students reported that there was a negative perception of teaching (Figure 14), and there was not much variation in response to this question from one discipline to another. However, as shown in Figure 15, students reported a substantial difference concerning the extent to which middle and high school teaching are discussed as a career option. More than half the mathematics students said this subject was discussed, while in computer science the students saying so were less than 10%. Chemistry and physics fell between these two extremes, with about a quarter of the students saying that teaching was discussed as a career in the department.

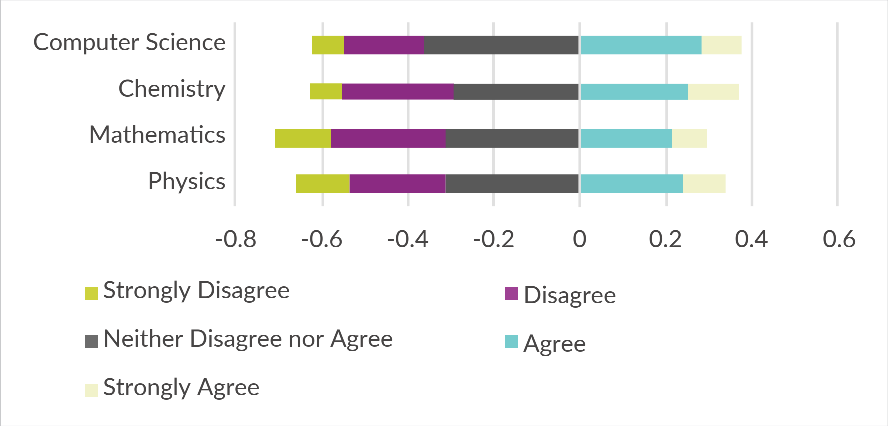


FIGURE 14
Response of those slightly, somewhat, quite a bit, or very interested in teaching to statement "There is a negative perception of choosing middle or high school teaching as a career in my major department."

The PhysTEC program specifically targets physics departments to help them become more supportive of teaching. Although the sample of undergraduates from PhysTEC-supported universities was not very large (only 22 physics undergraduates at PhysTEC-supported schools ended up in the sample), the comparison with undergraduates from non-PhysTEC schools is significant ($p(\chi^2)<.01$), as shown in Figure 15(B). At PhysTEC schools, undergraduate physics majors with some interest in teaching were twice as likely to say teaching is discussed as an option in their department.

It might seem possible that different disciplines have widely varying cultures of discussing career choices with students. However, this does not seem to be the case. All the students not interested in teaching were asked to comment on whether their non-teaching career choices were discussed in their major department. More than half the students agreed and the various majors did not differ from each other significantly (Figure 16).

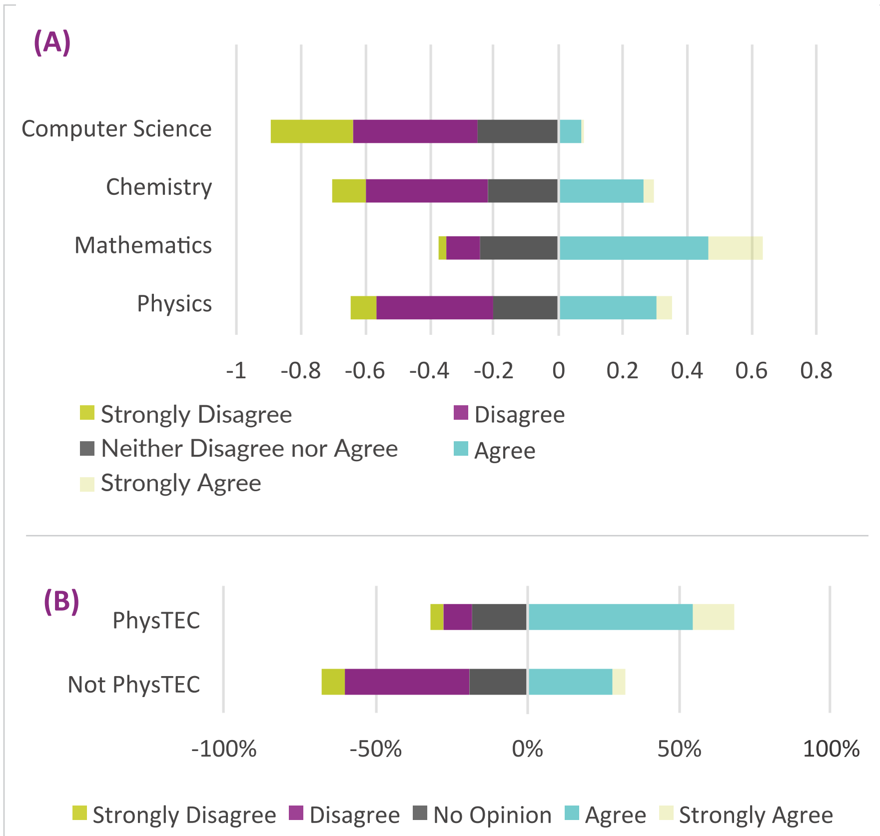


FIGURE 15

(A) Response of those slightly, somewhat, quite a bit, or very interested in teaching to statement "Middle or high school teaching is discussed as a career option in my major department."

(B) Response of physics majors to same question, depending on whether their department was a PhysTEC supported site or not.

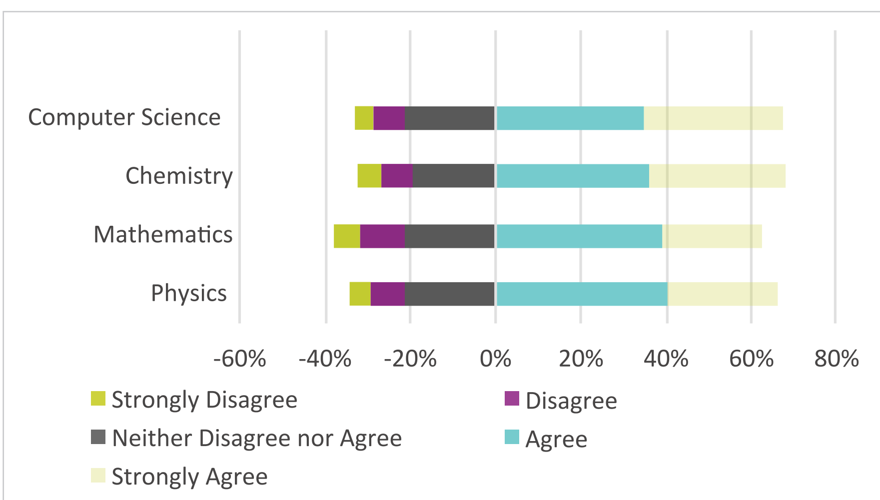


FIGURE 16

Response of those not interested in teaching to statement "My career choice is discussed as a career option in my major department."

SECTION 7

Conclusions and Recommendations

Salary

STEM majors in college think teachers make less than they actually do. Correcting this impression may provide one of the easiest ways to recruit more teachers into hard to staff STEM teaching fields. Furthermore, when students are asked what salary they would require in order to enter teaching, the salary they choose is close to the value that teachers actually get, both at entry, and also after five years of experience. The main exception is for computer science, where students who would consider teaching expect approximately $5K/year more than is typically offered in their regions.

For students and degree holders with an interest in teaching, it will be worth pointing out that middle and high school teaching pays more on average than the lecturer positions that are becoming more and more numerous in higher education. Furthermore, teaching salaries were favorable compared with salaries of other recent graduates in our sample, even after the comparison was restricted to those not in graduate school who had begun to work. The compensation comparison might become even more favorable when the value of health benefits and retirement plans is factored in.

At the same time. Figure 5 indicates that US middle and high school teachers earn less than other STEM workers with similar academic credentials, in contrast to countries like South Korea, Spain, and Canada where teachers earn as much or more than comparably educated workers (OECD, 2015). The teachers in our sample were half as likely as other graduates to say they were satisfied with their salary (Table 5), although according to Figure 13 they are actually earning as much or more than most of them. Nevertheless it is unlikely that an information campaign alone will suffice to eliminate teaching shortages, particularly in computer science.

SALARY INCREASES FOR TEACHERS

Noyce Teaching Fellows provide another track of the NSF Noyce competition. STEM professionals are eligible to become Teaching Fellows and receive both support to complete a master's degree and a salary supplement of $10,000/year for four years once they begin teaching.

Math for America awards four-year fellowships to accomplished mathematics and science teachers, who join STEM communities of critical thinkers, collaborative learners, and receive a $60,000 stipend.

Summer Stipends Many summer programs involving teachers such as summer research internships pay them a stipend that increases their annual compensation.

HIGH-QUALITY ACADEMIC PROGRAMS

PhysTEC is a project of the American Physical Society and the American Association of Physics Teachers whose mission is to improve and promote the education of future physics teachers. PhysTEC supported sites develop their physics teacher preparation programs into national models by implementing a set of key components experts identified as critical to success in physics teacher preparation. There are currently over 40 PhysTEC supported sites and over 300 universities in a broader coalition. phystec.org.

UTeach is a program that enables universities to prepare STEM teachers. Elements of the UTeach model include early field experience led by Master Teachers, research-based coursework, compact degree plans for students leading to a major and teaching certificate at the same time, and collaboration between faculty specializing in content and pedagogy. UTeach began at The University of Texas at Austin and has expanded to 45 universities. uteach.org.

Incentives

All of the incentive programs we examined—access to high-quality preparation, limited time needed for certification, loan forgiveness, free tuition for certification courses, scholarships—increased student respondents' reported interest in teaching. The effects are greatest for students who indicated an initial interest in teaching, with around 80% typically saying for each program that it would increase interest in teaching a bit, somewhat, quite a bit, or very much. For students without an initial interest in teaching, only 40% had their interest increased by incentives. Looking at the different disciplines, physics and computer science students will be the tougher sell; they are only 40%-70% as likely to say they would be swayed by incentives as mathematics and chemistry students.

While an increase in teaching salary causes the largest number of students to say it would interest them in teaching, this is also the most difficult change to implement. According to our survey results, an annual increase of $5K would provide CS majors willing to consider teaching with the salary they say they would need to stay past five years. Labor statistics show that an increase of $25K/year would be needed to bring their annual salaries in line with competing professions, although it should be noted that many teachers work less than 12 months per year. A salary increase sufficient to draw significant numbers of new teachers into the profession most probably lies between these two values. One possible policy response at school, district, or state level would be to raise teacher salaries in declared shortage areas in $5K steps, monitoring retention of inservice teachers, and production rate of new teachers for evidence that retention and production reach values able to eliminate shortages over a five-year period. The practical difficulties of such policies would be considerable, but one must consider for subjects such as computer science and physics the possibility that nothing else would be effective to fully solve national teacher shortages in high-need STEM fields.

Job Satisfaction

When students contemplate teaching they are most attracted to the idea of mentoring or positively impacting the next generation, and most worried about classrooms with disobedient or uninterested children. Practicing teachers, by comparison, worry much less about misbehaving students and are more concerned with non-teaching activities and unresponsive administration. Preservice teacher concerns about classroom conditions can be reduced through carefully structured early teaching experiences, such as the two first classes in the UTeach program sequence.[1]

1 For more information, see bit.ly/UTeachPDS

Practicing teachers are less satisfied with salary than other degree holders in their disciplines, but they are six times as likely to say that they feel their job makes a difference in other peoples' lives and they feel their jobs have more stability. Finding the right job is not simply a matter of getting the highest salary. Teaching has some particularly rewarding features that other jobs do not match, and both non-teachers and teachers recognize their appeal. A recent report from the United Kingdom (Menzies et al, 2015) emphasizes in more detail many of these same points. Thus prospective teachers should be encouraged to fully consider the pros and cons of teaching, and to challenge assumptions such as that children are unmanageable, that teaching is not intellectually challenging, or that they could easily earn more in other jobs.

Even if strong students are recruited into STEM teaching, some may not stay due to conditions in some schools. Here are the comments of a physics degree holder who had gone into teaching and left.

> *I was a high school teacher (hired on to teach physics and was switched to chemistry one week before I started my new job). I absolutely loved teaching. My high school kids were amazing whether they were tough to deal with or not. Teaching them chemistry concepts with fun and engaging activities was the height of my day. However, a year into teaching I was forced to conform to departmentally approved activities. Less hands on work, more worksheets, or virtual labs were the chosen activities by my department because it was less prep work for the teacher. I instantly saw my students' morale and excitement start to diminish. I was willing to deal with the low pay, long hours, teacher gossip, buying my own lab materials, and multitude of state mandated testing until they took away my freedom as a teacher. I was not allowed to do any of my own activities, and mainly for this reason I quit teaching mid-year to go back to school to ensure a career in which I may grow and learn every day.*

Stemming the loss of well-qualified teachers by improving conditions in schools to support excellent iteaching would help reduce the need for new teachers. At the same time, it is important to note that a common perception that most teachers leave the profession within five years is not borne out by data; around 80% of teachers are still teaching at the five-year mark (Gray, Taie, and O'Rear, 2015). The UTeach program reports a similar retention rate for its STEM teachers (UTeach, 2016). Teaching has special rewards:

> *I love seeing my kids excited about AP Physics and engineering, based on their enthusiasm with their projects or the cool questions they ask (I know their wheels are turning). On the flip side, I love when my repeat-Geometry juniors & seniors finally "get it"! It's also exciting when a whole class scores advanced or proficient on an end of course state exam or get a 4 & 5 on their AP physics exam.*

FINANCIAL SUPPORT TO PURSUE TEACHING

Noyce Scholarships are available through competitive awards to colleges and universities from the National Science Foundation. Both undergraduates and degree-holders are eligible for financial awards at selected universities. Undergraduates receive at least $10,000 per year up to the cost of attendance, and incur a two-year obligation to teach in a high-needs district for each year of financial support

TEACH grants from the US Department of Education provide up to $4000 per year to college and university students who agree to teach in high-need fields in high-need elementary, middle, and high schools. Mathematics and science are currently listed as high-need fields.

ACS-Hach Land-Grant Scholarships give undergraduates pursuing careers as high school chemistry teachers $10,000/year for full time study at 72 partner institutions. Chemists who have already completed their undergraduate degree are eligible to apply for the post-baccalaureate and second-career teacher scholarships, which provide $6,000 per year for full-time study and $3,000 per year for part-time study.

PROFESSIONAL SOCIETY ACTIVITIES

Scientific professional societies can take the lead in distributing information to disciplinary departments and college and university faculty about the importance of discussing teaching with students, and about conveying realistic advantages and disadvantages of careers in high school teaching. Professional societies can also encourage members working outside academia to participate in activities that improve the professional life and community of STEM teachers.

Departmental Support

Departmental support for middle and high school teaching varies greatly by major. The department where faculty and staff are most likely to discuss middle and high school teaching—mathematics—is also the department where the greatest fraction of students is interested in teaching. In computer science, where faculty and stuff are least likely to discuss middle and high school teaching as a career, students are least likely to consider teaching as a career. Physics and chemistry are in the middle. It is possible that we could recruit many more students to chemistry, physics, and computer science teaching if the faculty members in those departments were as supportive as mathematics faculty.

Recommendations

1. Impress upon university faculty and advisors in STEM disciplinary departments the importance of promoting middle and high school teaching with their undergraduate majors and graduate students, and of providing them accurate information about the actual salary and positive features of teaching.

2. Support high-quality academic programs that prepare students for STEM teaching, and expand good models to more universities. Strong programs provide improved coursework, prevent certification from requiring extra time, and support their students and graduates financially and academically.

3. Support expansion of programs that provide financial and other support for students pursuing STEM teaching.

4. Advocate for increases in annual compensation, including summer stipends, on the order of $5K-$25K for teachers in the hardest to staff STEM disciplines.

5. Support programs that improve the professional life and community of STEM.

PROFESSIONAL LIFE AND COMMUNITY

Math for America awards four-year fellowships to accomplished mathematics and science teachers, who join STEM communities of critical thinkers, collaborative learners, and acclaimed experts. The goal is to replicate a Master Teacher model around the country. The program originated in New York City, and has spread to statewide implementation in New York, Los Angeles, Washington DC, Utah, Boston, and San Diego. mathforamerica.org

QuarkNet connects high school teachers and students with national labs. Activities are intense in the first year, with a one-week boot camp and seven-week research appointment, but the goal is to establish long-term relationships. QuarkNet involves centers at 53 universities and labs, 18 high energy physics experiment, 475 high schools in 28 states, and 60 ,000 students per year. quarknet.i2u2.org

Columbia University Research Program for Science Teachers: This program, active for more than 25 years, enables science teachers to engage in hands-on laboratory research under the mentorship of Columbia University faculty for 16 weeks in two consecutive summers and to participate in weekly professional development. Among programs of this type, this one stands out for the care with which Silverstein et al (2009) documented positive learning outcomes for the students of participating teachers. scienceteacherprogram.org

ACS-Hach grants to high school chemistry teachers already in the classroom offer up to $1,500 in support of professional development, resources, activities, and laboratory equipment that enhance chemistry instruction.

ACKNOWLEDGMENTS

The idea for the survey developed when directors of UTeach (MM) and PhysTEC (MP) reached the conclusion that more than program development will be needed to fully solve teacher shortages in high-need STEM fields. After approval by the American Physical Society Panel on Public Affairs, funding was not clearly adequate to conduct the study, and we were fortunate to receive financial assistance from the American Chemical Society, thanks to the assistance of Mary Kirchhoff and Terri Taylor, who also supplied the ACS mailing list. At the American Institute of Physics, Rachel Ivie and Susan White conducted the survey for the non-CS sample, cleaned and assembled all the final data, and introduced us to or reminded us of ordinal logistic regression. To obtain results from the mathematics community, Uri Triesman pointed us to Howard Gobstein, who pointed us to Ed Dickey and Karen Campbell, who contacted many mathematics departments, which in turn enabled us to contact students. The largest cohort of students was provided by the Computing Research Association, where Andrew Bernat put us in touch with Jane Stout. She played a major role in taking our original ideas and turning them into a professionally organized survey, patiently tutored us about the risks of double-barreled questions, administered the survey on behalf of CRA, and delivered results to AIP. Final thanks to Francis Slakey, Ted Hodapp, and other members of the American Physical Society who read drafts and provided comments, and to members of the Panel on Public Affairs for their noteworthy engagement in this first education study conducted by the committee.

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70%
8 400
4 900
2 100
27%
73%
8%