National Task Force on Teacher Education in Physics: Report Synopsis

Transforming the Preparation of Physics Teachers: A Call to Action

Except for a handful of isolated pockets of excellence, the national system of preparing physics teachers is largely inefficient, mostly incoherent, and massively unprepared to deal with the current and future needs of the nation's students. Physics departments, schools of education, university administrators, school systems, state agencies, the federal government, as well as business and foundations, have indispensable collaborative roles to play so that *every high school student has the opportunity to learn physics with a qualified teacher.*

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National and International Contexts

National need for physics teachers

In the United States there are over 23,000 teachers of high school physics who serve students in over 20,000 public and private high schools. While many of these high school physics teachers are excellent educators, we are concerned that only a third of U.S. physics teachers have a major in physics or physics education. While about 400 high school physics teachers are hired each year with such qualifications, the rate at which we need new teachers in classrooms to fill gaps produced by retirement or individuals taking other positions outside of teaching is approximately 1,200 per year. In many states, weak standards for certification or endorsement to teach physics hide the fact that many teachers of physics lack the content knowledge and focused pedagogical preparation necessary to provide an excellent physics education for all students. The scarcity of qualified physics teachers is exacerbated by the annual increase in both number and fraction of high school students who take physics.

Pre-high school science education challenge

The latest science achievement data from two international assessments indicate that U.S. students arrive in high school science classes behind their counterparts in other industrialized nations. In the 2006 Program for International Student Assessment (PISA), U.S. 15-year-old students' average science literacy score of 489 was lower than the Organization for Economic Cooperation and Development (OECD) average of 500, and placed U.S. 15-year-olds in the bottom third of participating OECD nations. Between 2000 and 2006, the number of countries scoring higher than the United States on the PISA science assessment rose from 6 to 12. Similarly, at grade eight in the 2007 Trends in International Math and Science Study science assessment, the average U.S. science score was lower than those of students in 9 industrialized countries, including Russia, Japan, South Korea, and England. Without a strong physics education, differences in middle school science achievement between students in the U.S. and in other industrialized countries cannot be bridged easily during the high school years, especially in view of our anemic production of well-prepared physics teachers.

Economic implications

This is not an academic difference—it affects almost every aspect of the Knowledge- and Technology-Intensive (KTI) industries in the nation. There is a causal link between substandard student achievement in science in the U.S. and the urgent need for foreign-born STEM workers to fill critical positions in the U.S. science and technology sector. According to the *Science and Engineering Indicators 2010*, in 2003, 27% of Physics/Astronomy Bachelor's and 40% of Ph.D. recipients were foreign-born. Given the continuing increase in foreign participation, it is likely that these 2003-based percentages are conservative estimates. A National Science Board taskforce noted that "global competition for S&E talent is intensifying, such that the United States may not be able to rely on the international S&E labor market to fill unmet skill needs." An effective precollege physics education is indispensable in preparing U.S. students for global competition.

Unequal opportunities to learn physics

In addition to impacting negatively the nation's economy and security, inadequate science education threatens the very foundation of our democracy, as our educational system fails to provide members of racial and ethnic minorities and the poor with the knowledge and skills they will require to participate meaningfully in crucial social decisions of ever increasing scientific and technological complexity. For instance, on the 2005 eighth grade National Assessment of Educational Progress in science, the achievement gaps between Caucasian and African American students, between Caucasian and Hispanic students, and between low-poverty and high-poverty students were roughly equivalent to three whole years of learning. Unequal access to good science extends to our nation's high schools. While the percentage of African American and Hispanic high school students taking physics is increasing, their participation (23% and 24%, respectively) still lags behind that of Caucasian students (36%). High poverty schools, which also tend to have high percentages of students from groups underrepresented in the sciences, are less likely to offer advanced physics (AP or second year) and more likely not to offer physics at all. For example, 23% of high school students in New York City attend schools that do not offer physics, and these students are disproportionately poor and members of underrepresented groups.

National need for better prepared novice physics teachers

To be sure, the nation needs more teachers who themselves have a strong background in physics. More importantly, however, it needs educators who can lead others in developing a deep understanding of physics. Research on the effectiveness of the high school physics course and on student learning in physics paints an alarming picture. Studies correlating effects of matriculation in high school physics courses and success in the introductory physics course in college show that having taken high school physics has no larger an effect on success in the introductory college physics course than having taken high school mathematics instead. In addition, numerous physics education research studies conducted at the college level suggest that the overwhelming majority of students arrive in college without deep understanding of foundational ideas in physics, such as Newton's laws of motion. Of course there are counterexamples—there are many high school physics teachers who have a profoundly positive effect on their students' understanding of physics and love for physics. The challenge is to identify the knowledge, skills, and dispositions of such exemplars and build physics teacher education programs that focus intentionally on the development of these qualities in their prospective physics teachers in sufficient numbers to meet the national need.

Implications for the physics community

The state of high school physics ultimately affects the health of the physics profession. Physics faculty care about providing a substantive and meaningful encounter between their intellectual passion and their students (whether these students take one physics course or commit to becoming physics majors). Physics faculty should therefore also be concerned about the quality of that encounter before students reach them. A plausible causal chain connects students who receive sub-optimal physics instruction in high school with a decreasing fraction of physics majors relative to other STEM majors in college, which in turn affects physics department size and ability to attract U.S. physics graduate students. Public perceptions of the efficacy of physics as an enterprise also affect public funding for science research and university budget allocations for science programs. For members of the physics community, perhaps the most alarming prospect is that of a citizenry that fails to appreciate physics as a liberal arts discipline—its unique way of knowing and its unique approach to satisfying and stimulating curiosity about the natural world. Members of the physics community, particularly physics departments, need to recognize what they stand to gain by a transformed physics teacher professional preparation system and what they stand to lose by preserving the status quo.

National Response

Several high-profile reports have documented the need for boosting the production and improving the effectiveness of STEM teachers, and government, universities, businesses, and other organizations have responded. The Congressionally mandated Robert Noyce Teacher Scholarship program for prospective STEM teachers has seen its budget skyrocket in recent years. The National Math and Science Initiative seeks to replicate the UTEACH model (developed at the University of Texas at Austin) on a national level. The Science and Mathematics Teacher Imperative of the Association of Public and Land Grant Universities has infused a sense of urgency among university presidents to act in concert to improve STEM teacher preparation. Closer to home, the PhysTEC project, a joint effort of the American Association of Physics Teachers (AAPT), the American Physical Society (APS), and the American Institute of Physics (AIP), has increased dramatically the number of physics teachers produced at its Primary Program Institutions and raised awareness related to issues in physics teacher preparation around the nation.

Traditional teacher preparation systems, however, do not typically accommodate these discipline-specific needs. While efforts to improve STEM teacher education are making a real and significant difference, systemic problems run deep and much work remains to be done. In the case of physics, departments often teach physics courses through the use of instructional methods that have been shown to be ineffective in helping students learn. Schools of education often teach content-free methods courses, emphasizing general strategies rather than specific instructional responses to address specific student ideas in a specific topical area. Student teaching often occurs in classrooms in which the cooperating teacher does not have the preparation or disposition to help the candidate develop into an effective novice physics teacher. In short, the parts of the physics teacher education system are often isolated from one another. Even worse, partly because of the small number of prospective teachers, physics teachers education tends to be marginalized in higher education institutions—teacher education is marginalized in physics departments and the education of physics teachers is marginalized in schools of education.

To lead the physics community in a response to the national and international debate on accountability and pressure for drastic improvements in pre-college science education, AAPT, APS, and AIP formed the National Task Force on Teacher Education in Physics (T-TEP). The Task Force was charged with investigating the following questions:

- Increasing the number of qualified teachers—Are there generalizable, yet flexible, strategies that institutions, and in particular physics departments and schools or colleges of education, can employ?

- Identifying best practice—Are there effective (a) strategies in recruitment, (b) models of professional preparation, and (c) higher education systems of support during the first three years of teaching?

- Research, Policy, Funding Implications—Are there characteristics of physics departments, special partnerships, and types of institutional support and extramural funding that foster effective programs? Are there important new research agendas in teacher professional preparation in physics, which can be identified and promoted? What new measures of discipline-based teaching effectiveness need to be developed? What new funding avenues and policy changes need to be in place to support these cutting-edge research and development efforts?

In response to its charge, the Task Force has taken the following actions:

- Consulted (a) extant research results on teacher education, induction, and teacher turnover, (b) the physics education research literature, and (c) national reports related to student achievement in STEM

- Analyzed multiple types of publicly available data to take stock of the current situation in physics teacher preparation in the U.S.

- Surveyed all 758 physics departments in the nation and used the survey results (79% response rate) to obtain quantitative teacher production data, enumerate pathways to certification and endorsement in different states, and identify institutions that produce annually two or more physics teachers

- Interviewed faculty or staff in identified institutions to verify and enrich survey data

- Conducted site visits to institutions that emerged as local, regional, or national leaders in the production of physics teachers and/or had promising and potentially replicable high quality programs

- Collaborated with other organizations with which it has a shared interest in teacher education, such as the Science and Mathematics Teacher Imperative of the Association of Public and Land Grant Universities, the American Association of Colleges of Teacher Education (APLU), the Knowles Science Teaching Foundation, and the American Chemical Society

- Sought advice from teacher education experts, program officers at foundations, and policy makers

- Produced findings and recommendations that are unanimously endorsed by the Task Force members.

References

1. For recent national and international precollege assessment data in science, see, Gonzales, P., Williams, T., Jocelyn L., Roey, S., Kastberg, D., and Brenwald S. (2008) Highlights From TIMSS 2007: Mathematics and Science Achievement of U.S. Fourth- and Eighth-Grade Students in an International Context, National Center for Education Statistics publication 2009001; Baldi, S., Jin, Y., Skemer, M., Green, P.J., Herget, D. (2007) Highlights from PISA 2006: Performance of U.S. 15-Year-Old Students in Science and Mathematics Literacy in an International Context, National Center for Education Statistics publication 2008016; Grigg, W.S., Lauko, M.A., and Brockway, D.M. (2006) The Nation's Report Card: Science 2005. National Center for Education Statistics publication 2006466.

2. National Science Board. Science and Engineering Indicators 2010. http://www.nsf.gov/statistics/seind10/ Retrieved 01/28/2010.

3. Neuschatz, M., McFarling, M., White, S. (2008) Reaching the Critical Mass: Findings from the 2005 Nationwide Survey of High School Physics Teachers. College Park, MD: American Institute of Physics. Kelly, A.M., Sheppard, K. (2008). Newton in the Big Apple: Access to high school physics in New York City. The Physics Teacher, 46(5), 280-283.

4. For correlations between characteristics of high school physics teaching and success in college physics, see, Tai, R.H., Sadler, P.M., Mintzes, J.J. (2006) Factors Influencing College Science Success, Journal of College Science Teaching, 36 (1), 52-56, and Sadler, P.M. and Tai, R.H. (2001) Success in Introductory College Physics: The role of high school preparation, Science Education 85 (2), 111-136.

5. For a bibliography of research on the learning and teaching of physics, see, McDermott, L.C., and Redish, E.F. (1999) Resource Letter: PER-1: Physics Education Research, American Journal of Physics, 67 (9), 755-767.

6. Selected reports on the status of STEM education includes Carnegie Corporation-Institute for Advanced Study Commission on Mathematics and Science Education (2009) The Opportunity Equation: Transforming Mathematics and Science Education for Citizenship and the Global Economy, http://www.opportunityequation.org/ Retrieved 01/28/2010; Committee on Prospering in the Global Economy of the 21st Century (2007) Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future. Washington, DC: National Academies Press; and National Commission on Mathematics and Science Teaching for the 21st Century (2000) Before It's Too Late: A Report to the Nation http://www2.ed.gov/inits/Math/glenn/report.pdf Retrieved 01/28/2010.

Findings

Through surveys, interviews, site visits, consultation of extant research data, and collaboration with other national initiatives, T-TEP found that

1. **Few physics departments and schools of education are actively engaged in the recruitment and professional preparation of physics teachers.**

   Fewer than one quarter of physics departments and schools of education have a physics teacher education program with recent graduates. The great majority of programs have very low graduation rates with fewer than two students per year, making it difficult to justify needed resources. The graduates from physics education programs are about one-third as many as the annual national need for new physics teachers.

2. **Without exception, all of the most active physics teacher education programs have a champion who is personally committed to physics teacher education. With few notable exceptions, these program leaders have little institutional support.**

   At institutions that produce an average of two or more physics education graduates per year, there is invariably at least one individual deeply committed to physics teacher education who invests substantial time and effort in the work of advising, supporting, and mentoring future teachers. Except in very special cases, traditional systems of promotion and tenure often provide little reward for this work, and programs typically have few resources, limiting the extent of program activities.

3. **Institutional context appears to be a significant factor in the engagement of physics departments in physics teacher education.**

   PhD-granting physics departments typically have larger undergraduate physics programs than Bachelor's and Master's degree-granting departments. Yet, Bachelor's and Master's institutions are more likely to have an active physics teacher education program (23%) than their PhD counterparts (13%). Also, Bachelor's and Master's degree-granting departments graduate a much larger proportion of their physics majors from physics teacher education programs than do PhD-granting departments. In addition, there are strong indications that institutions with a reputation for teacher preparation (e.g., former Normal schools) produce more physics teachers than do institutions lacking such a reputation.

4. **Few institutions demonstrate strong collaboration between physics departments and schools of education.**

   Both physics and education departments tend to review their requirements for prospective teachers independently, often resulting in a lack of intellectual coherence, as well as a proliferation of requirements. The unfortunate outcome is that many prospective teachers forgo a year's professional compensation by being forced to stay in school longer. Physics departments are rarely involved in placement or evaluation of student teaching or other field experiences, despite the relevance and importance of content knowledge in these experiences.

5. **Programs do little to develop the physics-specific pedagogical expertise of teachers.**

   Few programs have even a single course specific to the teaching of physics, let alone a well-developed sequence of courses. Even though student teaching typically occurs in a physics classroom, little support is provided to candidate teachers to help them develop an understanding of student ideas about physics or specific strategies to build on these ideas.

6. **Few programs provide support, resources, intellectual community or professional development for new physics teachers.**

   Very few programs maintain contact with their recent graduates on a consistent basis. This leaves them unable to provide any ongoing support for their graduates on matters such as ideas for curriculum, assistance with conceptual or instructional questions, or help with equipment. With few notable exceptions, programs do not provide opportunities for recent graduates and soon-to-be graduates to meet together and discuss issues of common in-terest. Such lack of professional support systems is especially pronounced for physics teachers, 79% of whom are the only physics teacher in a school.

7. **Few institutions offer a coherent program of professional development for in-service teachers, even though most teachers of physics are not adequately prepared to teach physics.**

   Only one third of the 23,000 physics teachers in the U.S. have a degree in physics or physics education; the rest typically have taken no more than a sequence of introductory physics courses. Many institutions offer professional development for teachers, but few provide a coherent program of integrated content and physics-specific pedagogy so that in-service teachers can acquire the comprehensive knowledge they need to teach physics.

Despite this grim national picture, we also found that

8. **There exist thriving physics teacher education programs that can serve as models and resources for other institutions.**

   Thriving programs often enjoy significant levels of institutional and external support. Different programs have different strengths and although not all programs are strong in all areas, such programs include a number of the following features:

   - A program champion or a group dedicated to physics teacher education
   - Active collaboration between physics and education departments
   - A sequence of courses that are focused on the teaching and learning of physics
   - Early teaching experiences led by the physics department
   - Individualized advising of teacher candidates by faculty knowledgeable about physics education
   - Mentoring by expert physics teachers
   - A rich intellectual community for graduates

Although small in number, thriving programs exist at a variety of colleges and universities, including research intensive, regional comprehensive, and liberal arts institutions.

Recommendations

The Task Force recommendations respond to the findings identified throughout the two-year investigation, as well as in the synthesis of relevant literature on science teacher education and development. The recommendations are grouped in three categories: Commitment, Quality, and Capacity. A well recognized commitment to physics teacher education is necessary, as are specific efforts to improve the quality of teacher professional preparation systems and boost the number of qualified physics teachers.

Commitment

Physics and education departments, university administrators, professional societies, and funding agencies must make a strong commitment to discipline-specific teacher education and support.

1. **Physics departments and colleges of education should recognize that they have individual and joint responsibility for the professional preparation of the physics teachers at their institution and should act accordingly.**

   Physics departments should recognize that all aspects of the teaching of physics at the institution, including the messages the department sends about the value of teaching and learning, have a profound positive or negative effect on the quality of subject matter preparation, values, and professional identity of future physics teachers.

   Colleges of education should recognize that physics teachers need specialized pedagogical knowledge in the learning and teaching of their discipline.

   Physics departments should become aware of the process for obtaining certification to teach physics; Colleges of education should become aware of the intellectual content and pedagogy needed for the physics-specific preparation of teacher candidates.

2. **Institutions that consider the professional preparation of STEM teachers an integral part of their mission must take concrete steps to fulfill that mission.**

   Institutions should join national or regional organizations (e.g., PTEC, APLU) committed to improving the quality of physics teacher preparation. Higher education presidents, provosts, deans, and department chairs must provide the requisite support for programs to flourish. Physics departments and colleges of education must select or recruit leaders for the physics teacher education program. They should support these leaders institutionally and reward them professionally.

3. **Professional societies and foundations must provide support and a coherent vision for the joint work of disciplinary departments and schools of education in teacher preparation.**

   Societies and foundations involved in education should disseminate results of research on physics teacher professional preparation and facilitate the development of innovative models for institutions of various sizes and missions.

4. **The National Science Foundation and the U.S. Department of Education should develop a coherent vision for discipline-specific teacher professional preparation and development.**

   In addition to federal agencies that are directly connected with teacher education and enhancement, state and private funders need to reverse the longstanding implicit or explicit segregation into preservice and inservice programs and funnel significant programmatic funding and scholarships ftothe professional preparation of teachers in STEM disciplines. To prepare future citizens to tackle 21st-century multi-disciplinary problems, teachers need deep grounding in the teaching of a particular discipline.

Recommendations

Quality

All components of physics teacher professional preparation systems should focus on improving student learning in the precollege physics classroom.

5. **To optimize the environment for students to consider teaching careers, as well as to maximize student learning and promote effective pedagogical practices, teaching in physics courses should be guided by findings published in the physics education research literature.**

   Physics instruction should take advantage of the extensive literature on student thinking in physics and the research-validated effectiveness of certain instructional approaches.

6. **Physics teacher preparation programs must provide teacher candidates with learning opportunities and extensive clinical experiences that allow them to genuinely integrate knowledge of (1) the discipline of physics, (2) general pedagogy, and (3) physics-specific pedagogy.**

   Physics courses should have a reflective component connecting the course material to the demands of the precollege classroom. Pedagogical courses should focus on learning and teaching of physics. Clinical experiences should occur in contexts that model effective physics learning environments for all students.

7. **Physics departments, colleges of education, school systems, and state Departments of Education should collaborate to provide mentoring to early career teachers.**

   As junior faculty are mentored in research groups, new teachers need an opportunity to be mentored by university faculty, their peers who graduated earlier, and school system representatives. Creating a professional learning community of physics teachers who share similar views of student learning will contribute to the reduction of professional isolation and consequently increase the retention of novice teachers.

8. **States should remove general science teacher certification and replace it with endorsements in individual subject areas, and work with higher education institutions to create new pathways that allow prospective teachers to receive more than one endorsement without increasing the length of the degree.**

   These new programs should contain the appropriate subject matter preparation for teaching more than one discipline and appropriate preparation in the discipline-specific pedagogy of each of these subjects. These new degree pathways will allow states to balance the oft-competing needs for more teachers who are certified and qualified, and more rigorous certification requirements, while providing greater marketability for teachers and retaining the flexibility needed by small or rural school districts. States should assess knowledge of physics-specific pedagogy as a necessary content endorsement competence.

9. **National accreditation organizations should revise their criteria to better connect accreditation with evidence of candidates' knowledge of and skills with subject-specific pedagogy.**

   Even though the current accreditation systems intend to assess programs on the basis of candidates' competency with pedagogical content knowledge, the assessment is often based on candidates' subject matter coursework, general pedagogy coursework, and a small number of teaching experiences in the content area. Instead, the assessments should provide evidence of the candidates' knowledge and skills as they relate to helping students master specific physics concepts (e.g., nature of force) and specific physics process skills (e.g., collecting, analyzing, and modeling data).

10. **Education researchers should work to better define physics teaching quality and effective physics teacher preparation, as well as investigate the connection between student achievement and physics teacher knowledge, skills, and dispositions.**

    A research agenda should be developed to define and measure precollege and college student achievement in physics along multiple dimensions (conceptual understanding, quantitative problem-solving, nature of the discipline, etc.); define and measure appropriate knowledge for teaching physics; develop coherent research-validated curricula for physics teacher preparation; develop research-validated models that increase the number and quality of the nation's discipline-specific teacher educators; and investigate the needs of teachers of physics and physical science at the elementary and middle levels.

Capacity

Multi-partner collaborations should adopt bold strategies to boost the number of qualified individuals who will consider teaching physics as a vocation.

11. **Physics departments, colleges of education, and school systems should collaborate to adopt specific strategies that have demonstrated success in increasing dramatically the number of individuals with extensive background in STEM disciplines who are prepared to teach physics effectively.**

    Physics and education faculty must work with school district colleagues to present teaching as an intellectually complex and rewarding career with legitimate academic problems, research foundations, and methods of inquiry. Active recruitment of STEM majors, including STEM professionals, into physics teaching is a necessary strategy.

12. **Physics departments, colleges of education, and school systems should collaborate to develop a course of study that targets all necessary components for learning a specific topical area of physics.**

    Aligning physics teacher education programs with larger institutional and regional efforts can bring more resources, support and publicity to the program. Combining selected offerings for preservice teachers with professional development of inservice teachers has the potential to increase both physics course enrollments and program quality and improve the rigor and relevance of professional development programs for those who teach physics out-of-field.

13. **In collaboration with school systems, institutions or coalitions of institutions should increase their regional impact by pooling subject-specific teaching expertise and a diverse array of contexts to create communities of significant numbers of prospective and practicing physics teachers.**

    Federal, state, and private funding of regional centers for physics teaching may be one way to pursue this option. Regional centers may serve as models for discipline-based preparation and enhancement of STEM teachers. The existing exemplary programs for physics teacher preparation can serve as nuclei for such centers.

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