Physics Teacher Education in Perspective: A Century of Constrained Evolution

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Overview

The recommendations of the Task Force are consistent:

- with the specific findings of our own extensive investigation, and
- with the vast body of research and analysis generated by others who have examined these same problems during the past 130 years.

Excerpts from Task Force Report
Executive Summary

"Over the past 20 years, academic, business, and governmental authorities have warned that U.S. science teacher preparation needs a drastic overhaul, particularly in physics teacher education.…the preparation of qualified physics teachers has failed to keep pace with a dramatic increase in the proportion of high-school students taking physics.…

Excerpts from Task Force Report
Executive Summary

"… many current physics teachers lack the content knowledge and focused pedagogical preparation with which to help their students most effectively.…The potential negative consequences of maintaining the status quo are far-reaching for the U.S. economy and society, for physics as a discipline, and for physics departments at colleges and universities…"

Historical Overview

- The issues regarding physics teacher education that we address in this Report are not new.
- This is not the first investigation that has described the problems and made recommendations for improvement.
- From the earliest days of high-school physics teaching in the United States during the late 1800s, a shortage of qualified physics teachers has been noted and bemoaned (Clarke, 1880; Wead, 1884)

Historical Review: Key Factor

- The great majority of U.S. high schools before 1910 were quite small (≈ three teachers *per school*), so they could not hire specialist physics teachers. (Mann, 1912)
- Prevalence of small schools persisted into 1960s; helped ensure that over 80% of U.S. physics teachers in the mid-1960s spent the majority of their time teaching subjects other than physics.

Persistence of Problem

- With limited demand for specialist instructors, the very existence of programs to train well qualified physics teachers was usually considered cost-ineffective and thus virtually untenable from the start.
- Even so, the supply of qualified high school physics teachers has long been considered to be a “critical” problem. (Strassenburg, 1967)
- In fact, essentially every report regarding science teacher education in the United States over the past century, with various degrees of urgency, has labeled the supply of physical science teachers as inadequate. (For extensive bibliography see Task Force Report, Appendix on Resources)

Post-War Developments

- Beginning in late 1940s, as a partial solution to the problem, summer institutes sponsored by universities or private companies were established to offer enrichment programs for in-service teachers of physics (also math and other sciences).
- After Sputnik (1957) the number of these institutes expanded dramatically at the insistence of the U.S. Congress, with funding provided by the National Science Foundation. (Kreighbaum and Rawson, 1969)

AAAS Recommendations

- A variety of organizations addressed the science teacher supply problem and made recommendations for improvements. For example:

  "Scientists should recognize, and persuade their students to recognize, that public school teaching is an important and challenging profession which merits consideration by persons of first-rate ability…Each institution preparing science teachers should create a committee of scientists, science teachers, and professional educators to give attention to the development of science teacher education programs."

  Commission on the Education of Teachers of Science and Mathematics, American Association for the Advancement of Science and American Association of Colleges for Teacher Education,1960

Compare: Task Force Recommendation #2

- "Physics faculty should encourage students to consider teaching as a career option and they should ensure that interested students receive appropriate assistance in achieving this goal." (2a)
- "Physics faculty should encourage their best students to consider teaching and should promote the academic study of teaching as an intellectually challenging endeavor." (2b)
- "Physics faculty should build a relationship with those persons in the education department who are responsible for science teacher preparation and should assist students interested in teaching physics in contacting them." (2d)

NAS and AIP Join Discussion

- In 1966, the Physics Survey Committee of the National Academy of Sciences linked a “severe educational crisis for physics” in the high schools to a shortage of competent high school physics teachers.
  - *Physics: Survey and Outlook* (National Research Council, Washington, D.C., 1966), p. 30.
- The American Institute of Physics instituted aggressive programs during the 1960s to attempt to remedy the shortage of qualified physics teachers. (Strassenburg, 1967)

Commission on College Physics

- The Commission on College Physics carried out an extensive investigation of the preparation of high school physics teachers and published a detailed report in 1968 with a second, updated edition published in 1972.
  - Commission on College Physics, *Preparing High School Physics Teachers* [Report of the Panel on the Preparation of Physics Teachers of the Commission on College Physics], Ben A. Green, Jr., et al. (Department of Physics and Astronomy, University of Maryland,1968)
  - Commission on College Physics, *Preparing High School Physics Teachers II, revised edition* (University of Maryland, 1972).

Commission Findings

- The Commission asserted that “the shortage of qualified high school physics teachers is one of the most pressing problems facing American physics today”; it stated:

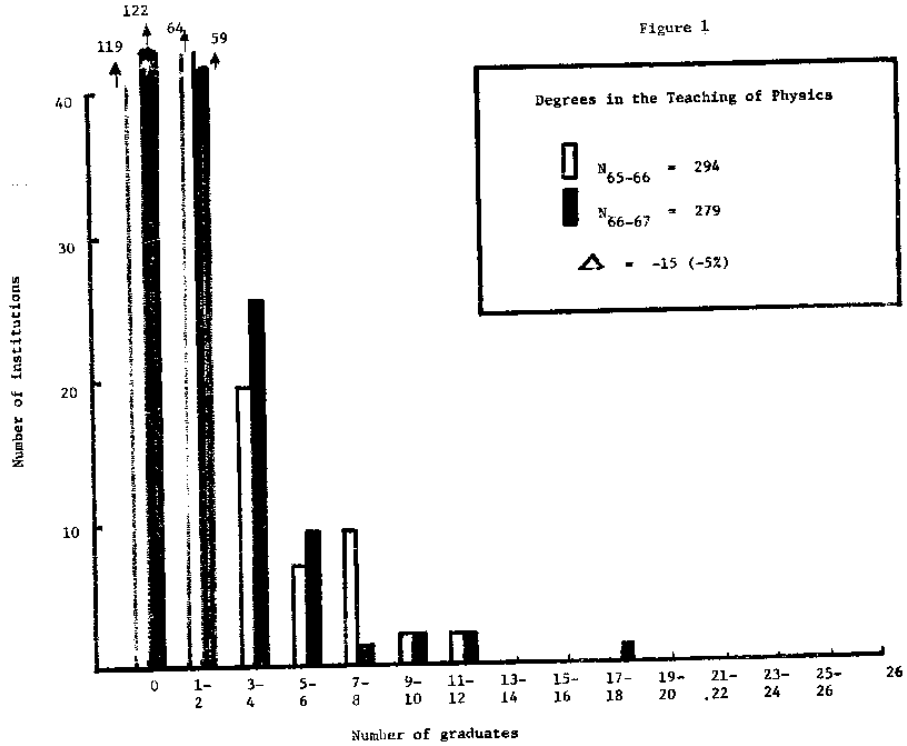
  “…well-known, high-prestige departments rarely have programs specifically tailored to the needs of the prospective high school physics teacher…These same departments typically graduate two or three teachers *every five years*…Less than ten of the schools surveyed graduate more than five physics teachers per year.”

- More than 40 years later, our Task Force finds that this situation has not changed *at all*.

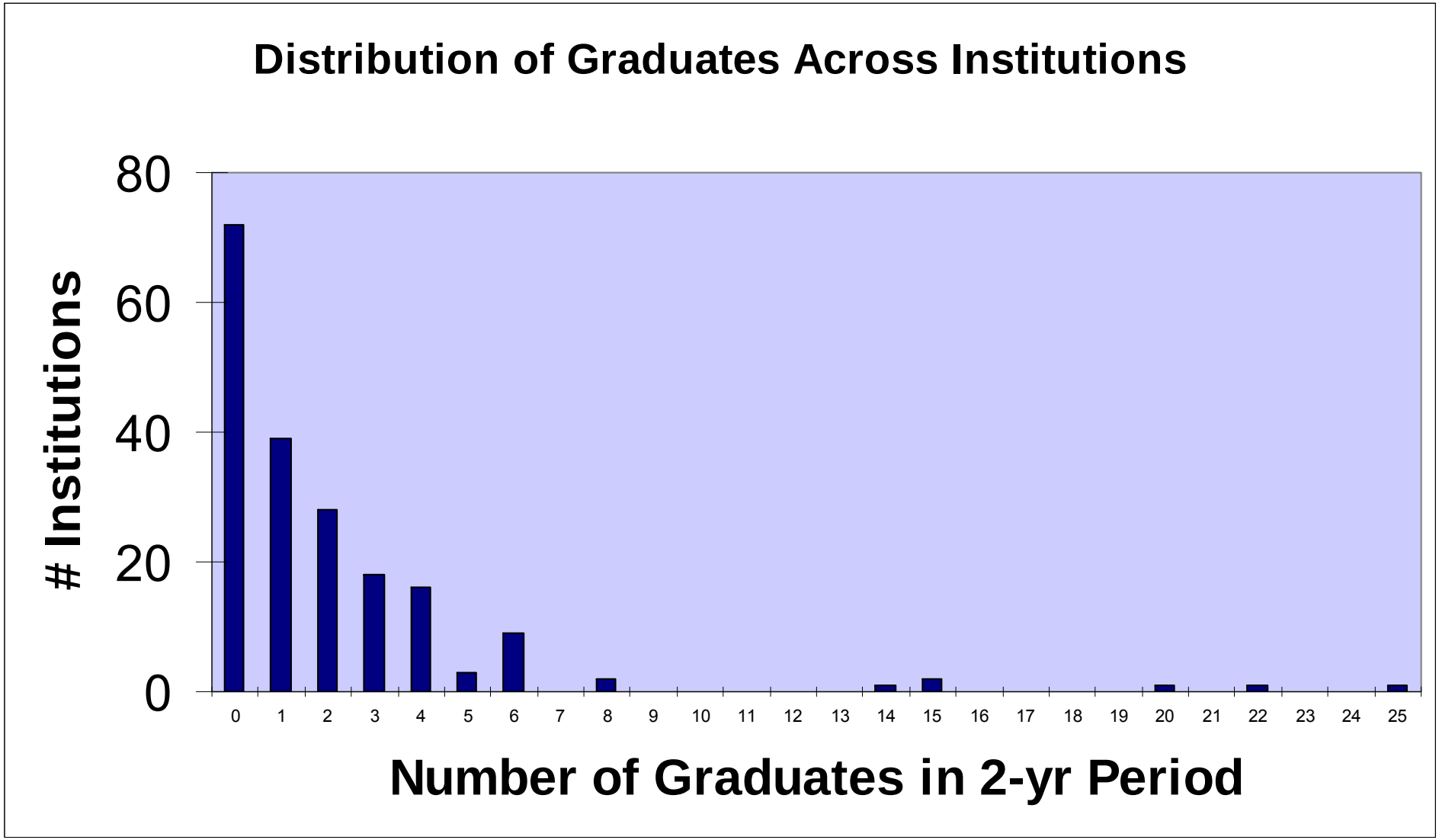
Distribution of Graduates

- A bar chart demonstrating the highly skewed distribution of physics teacher graduates from U.S. institutions—most institutions graduating zero or one per year, a tiny handful graduating more than four—can be found in a survey of science teacher education programs carried out in the mid-1960s. (Newton and Watson, 1968, p. 26)
- The analogous chart resulting from our own findings is essentially identical to this one (see Chapter 3).

Figure 1


Degrees in the Teaching of Physics
N_{65-66} = 294
N_{66-67} = 279
△ = -15 (-5%)
122
119
64
59
40
30
20
10
Number of institutions
0
1-2
3-4
5-6
7-8
9-10
11-12
13-14
15-16
17-18
19-20
21-.22
23-24
25-26
26
Number of graduates

[From Task Force Report (2012), Chap. 3]



Commission Recommendation

- The Commission stated that

  "it is clear that more physics departments should assume the responsibility of providing adequate training to prospective secondary school science teachers, especially prospective physics teachers."

  – Commission on College Physics (1972), *op. cit*., p. 9.

Compare: Task Force Recommendation #2

- "Physics departments should recognize that they have a responsibility for the professional preparation of pre-service teachers." [2]
- "Physics departments that have made teacher preparation part of their mission should develop a rigorous track for future physics teachers that is informed by the state standards that prescribe what has to be taught in high school…The rigor of the track should be derived not only from the physics content but also from a sequence of courses that are focused on the teaching and learning of physics. ." (2d)

Commission Finding: Program Champions

A member of the committee that prepared the updated 1972 Commission report noted that, with respect to colleges and universities having physics teacher preparation programs:

"The number of prospective physics teachers showed no correlation with the size of the institution; it depended almost invariably upon the amount of interest and concern actively expressed by one or more physics staff members at their institution."

– S. Winston Cram, as quoted in John L. Lewis, editor, *Teaching School Physics* (A UNESCO Source Book), (Penguin, Harmondsworth, England, 1972), p. 272.

Compare: Task Force Finding #2

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

Physics-Specific Pedagogy

- The Commission strongly advocated creation of physics courses *specifically* designed for and targeted at future physics teachers, incorporating active participation in both learning and teaching and more exposure to classroom situations. (1968 Report: pp. 7-8; 1972 Report: pp. 9-15)
- Such courses have long been accepted and implemented in many other countries as necessities for an effective physics teacher preparation program.
- Similarly, in other countries it is common for university-based teacher education programs to be led or assisted by physics education specialists with extensive school teaching experience. (Meltzer, 2011)

Compare: Task Force Recommendation #7

"…physics teacher preparation programs should include extended physics-specific instructional experiences. …Pre-service teachers also need specific instruction on how to teach various topics in physics. This instruction should be provided by physics master teachers, physics faculty, and/or physics education researchers." (7a)

"…Courses offered should include literature-based and practicum-based investigations of common student reasoning and thinking patterns in the various topics in physics, as well as effective methods for assessing student learning of these topics." (7b)

"Every teacher preparation program should include at least one pedagogical course that focuses on the learning and teaching of various topics in physics." (7c)

Consistency of Findings

- In the process of reviewing hundreds of reports, research papers, and policy statements regarding the education of physics teachers all over the world—beginning in the 1880s—we were struck by the consistency and reproducibility both of the findings and of the recommendations of the various committees, professional organizations, and independent researchers.
  - See Report, Appendix on Resources
  - See Meltzer, in *Teacher Education in Physics: Research, Curriculum, and Practice* (APS, 2011), pp. 3-14.

Research on Education of Physics Teachers

- There exist relatively few published studies in which the impacts of U.S. physics teacher education programs of any type have been carefully examined.
- However, a number of recent investigations have probed outcomes of teacher education programs in which there is a strong focus on physics-specific pedagogy using research-validated instructional methods of the type recommended in this Report. (Meltzer, 2011)

Physics by Inquiry Curriculum

- Preservice teachers taught lessons on light in a ninth-grade classroom using materials and methods they had themselves recently learned. Their ninth-grade students had much higher scores (45%) on post-instruction diagnostic tests than did undergraduate university physics students in traditional physics courses taking the same tests (20%). (McDermott et al., 2006)
- A summer program that used *Physics by Inquiry* reported strong learning gains among inservice middle-school and high-school physics teachers. Delayed tests administered 6-8 months after instruction found good to excellent retention of the learning gains. (Oberem and Jasien, 2004)

Modeling Instruction

- Students of teachers who participate in Arizona State University's "Modeling Instruction" inservice program have consistently shown much better performance on the "Force Concept Inventory" diagnostic test than students of teachers who had not been through that or any comparable program. (Hestenes et al., 1992; Wells et al., 1995; Hake, 1998; also see http://modeling.asu.edu/)
- Other evidence shows that both preservice and inservice teachers who participate in workshops using the Modeling method have better learning gains than students enrolled in more traditional learning environments. (Andrews et al., 2003; Vesenka, 2005).

Rutgers University

- The Rutgers University program for preservice physics teacher education is based on a sequence of courses on physics-specific pedagogy, founded on physics education research.
- Evaluations of program participants show that their knowledge of both physics concepts and science processes (such as experiment design) undergo dramatic improvements over the course of the program, with final scores showing high proficiency.
- These objective measures were consistent with evaluations by the students' mentor teachers and science supervisors. (Etkina, 2010)

U. Colorado Learning Assistant Program

- Extensive studies of students who participate in the University of Colorado's "Learning Assistant" preservice program have documented dramatic learning gains—not only in introductory-level physics courses but in advanced-level courses as well. (Otero et al., 2010)
- Follow-up observations and interviews with former participants in the program indicate that teaching practices of first-year teachers who had been in the program are more closely aligned with national science teaching standards than practices of comparable first-year teachers who had not been part of the program. (Gray et al., 2010)

“Constructing Physics Understanding”

- The Constructing Physics Understanding (CPU) project at San Diego State University incorporated summer and academic-year workshops targeted at inservice high school teachers. These incorporated inquiry-based investigative activities developed through physics education research.
- High-school students taught by workshop participants recorded higher scores on physics concept exams than students taught the same concepts by a very comparable group of teachers who had not taken the CPU workshops.
- The highest scores were recorded by students of teachers who had previous CPU experience and who had helped lead the workshops. (Huffman et al., 2003; Huffman, 2007)

International Research: Example

- An Israeli program guided inservice physics teachers to develop, and use in their classrooms, curricular materials and instructional methods based on physics education research.
- These teachers' students performed better on tests of electromagnetism concepts than did students at the same schools who used standard instructional materials. (Eylon and Bagno, 2006)

PTRA

- The Physics Teaching Resource Agent (PTRA) program, sponsored by the AAPT and funded by the NSF, has provided research-based workshops and curricular materials for inservice physics and physical science teachers since the 1980s. (Badar and Nelson, 2001; Burns, 2003)
- Although peer-reviewed studies of the effectiveness of these workshops have yet to be published, preliminary research data suggest that students of long-term workshop participants make gains in physics content knowledge that are significantly larger than those made by students of non-participants. (Matsler, 2004 and 2010)

Generalizability of Methods

- The programs described above are all specifically targeted at high-school physics teachers.
- However, outcomes from similar programs that focus on preparation of elementary- and middle-school physical-science teachers are consistent with the results discussed here. (For example, Goldberg et al., 2010; Loverude et al., 2011)

Summary

- The number, diversity, and consistency of research outcomes provide substantial evidence for the effectiveness of the methods recommended in the Task Force Report.
- The recommendations are also consistent with long-standing practices, philosophies, and research of teacher education programs in other countries that have demonstrated learning outcomes superior to those observed in the United States.
- The literature on physics teacher education in the U.S. and around the world indicates clearly that physics teacher education programs *can* be effective if they are thoroughly grounded in physics education research and sharply focused on developing expertise with physics-specific pedagogy.