Historical Survey of Research in Physics Teacher Preparation

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Outline

1. Historical Background: Recommendations and reality in physics teacher education
2. Research in Physics Teacher Education: A fundamental obstacle
3. Common Themes in Recent Research (1970-present)
    - Common Program Features
    - Commonly Observed Outcomes

1. Historical Background: Recommendations and Reality in Physics Teacher Preparation

Recommendations for U.S. Physics Teacher Education

- **1909:** Physicists recommend that teacher preparation should be at level of graduate student in physics
- **1920:** NEA Physics Committee Chair says “prospective teachers must approach all their teaching problems inductively….college science teachers must foster in prospective teachers the inductive rather than the cock-sure habit of mind.”
- **1960:** AAAS recommends 20-24 semester hours minimum

Recommendations for U.S. Physics Teacher Education

- **1968:** AAPT/AIP recommend minimum of 24 hours, or 18 hours plus "in-service training"
- **1968:** AAPT/AIP committee advocates courses for teachers using "learning by discovery" method: "This type of course leads a student to puzzle things through for himself, offering both the experience of being a scientist and the satisfaction that accompanies success.."
- **1973:** Physics Survey Committee (NAS) says "successful use of inquiry-directed instruction requires teachers who have themselves learned to investigate in this manner."

- **1920:** NEA Physics Committee Chair says “prospective teachers must approach all their teaching problems inductively….college science teachers must foster in prospective teachers the inductive rather than the cock-sure habit of mind.”

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G. R. Twiss [Chairman of NEA Physics Committee on Reorganization of Science in Secondary Schools] (1920)

A Model for Physics Teacher Education

“As to method, a very important part of the work is presented inductively. That is, physical changes are observed and described by members of the class; the conditions upon which these changes depend are then varied in many cases and in many ways, and in each case the pupils are asked to observe and describe.

A Model for Physics Teacher Education

“As to method, a very important part of the work is presented inductively. That is, physical changes are observed and described by members of the class; the conditions upon which these changes depend are then varied in many cases and in many ways, and in each case the pupils are asked to observe and describe. Wise questioning leads the class to distinguish that which is constant from that which is variable in these changes until the law which governs them comes spontaneously into view and is fully apprehended and formulated. With somewhat similar material and under somewhat similar circumstances the pupil repeats the work at his own table. Further illustrations, exercises, and problems follow.”

“Preparation of Teachers of Science…”
E. A. Strong [Prof. of Physical Sciences, Michigan State Normal School]
*Science **20**, 185 (1892)*

Recommendations by Physics Community for Teacher Education: Summary

- Preparation equivalent to a major or minor in physics (20-24 semester hours, minimum)
- Experience in, and ability to teach physics as hands-on, inductive “inquiry-based’ course

Attempts to Implement Recommendations

- **1939:** AAPT forms “Committee on the Teaching of Physics in Secondary Schools.”
- **1946:** AAPT reports on “deficiency in the number of well-trained science teachers.”
- **1947:** First summer institute for in-service physics teachers, sponsored by GE, to remedy deficient preparation.
- **1955:** First NSF-sponsored summer in-service institutes for physics and chemistry teachers
- **1966:** National Academy of Sciences cites “severe educational crisis for physics” in the high schools, links it to shortage of competent high school physics teachers.

Attempts to Implement Recommendations

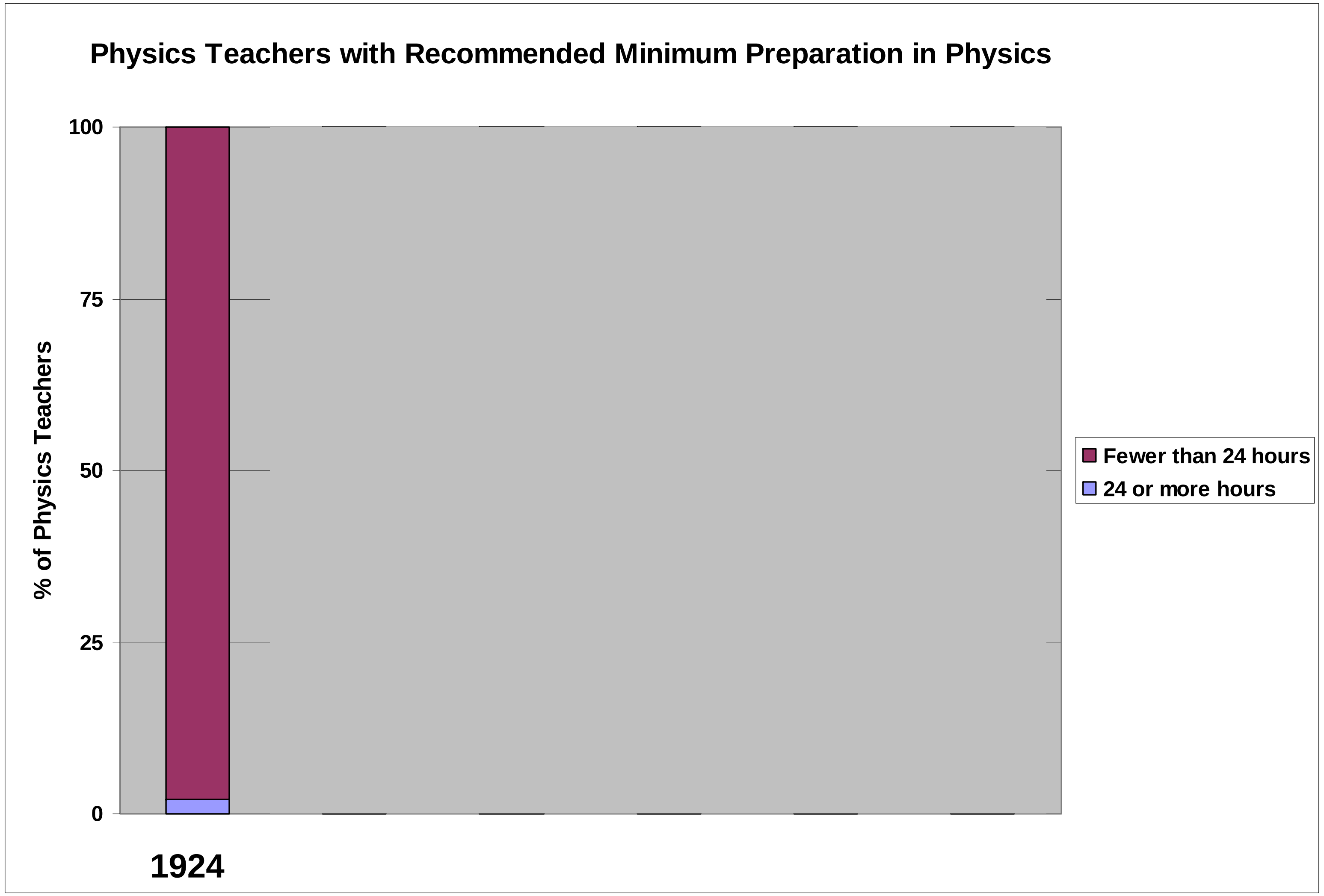
- **1968:** Following extensive investigation, Commission on College Physics (AAPT/AIP) issues report "Preparing High School Physics Teachers"
- **1973:** National Academy of Sciences issues new report, states that institutions should take active role in in-service physics education.
- **2012:** Following four-year investigation, release of report by Task Force on Teacher Education in Physics (T-TEP) [APS/AAPT/AIP].
  - Findings and recommendations consistent with those made in previous reports

Outcome: Most Physics Teachers Have Less Than Recommended Preparation

- Most U.S. physics teachers have now—and have always had—less than the recommended physics preparation, equivalent to a major or minor in physics (~24 semester hours)

- Average preparation has increased substantially over the years, but more than 50% of teachers still fall short

References: Dozens of physics teacher surveys, 1920s-present



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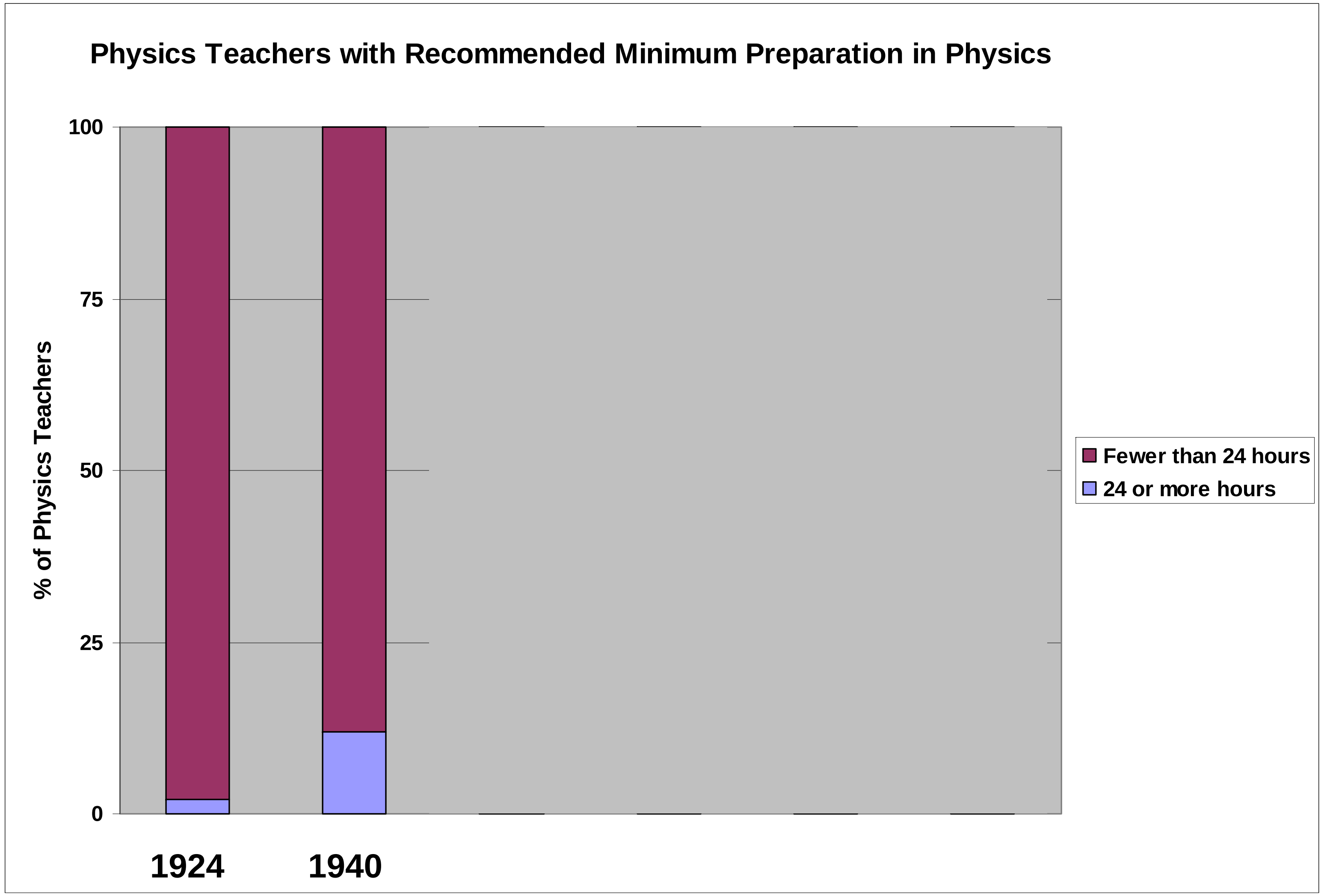

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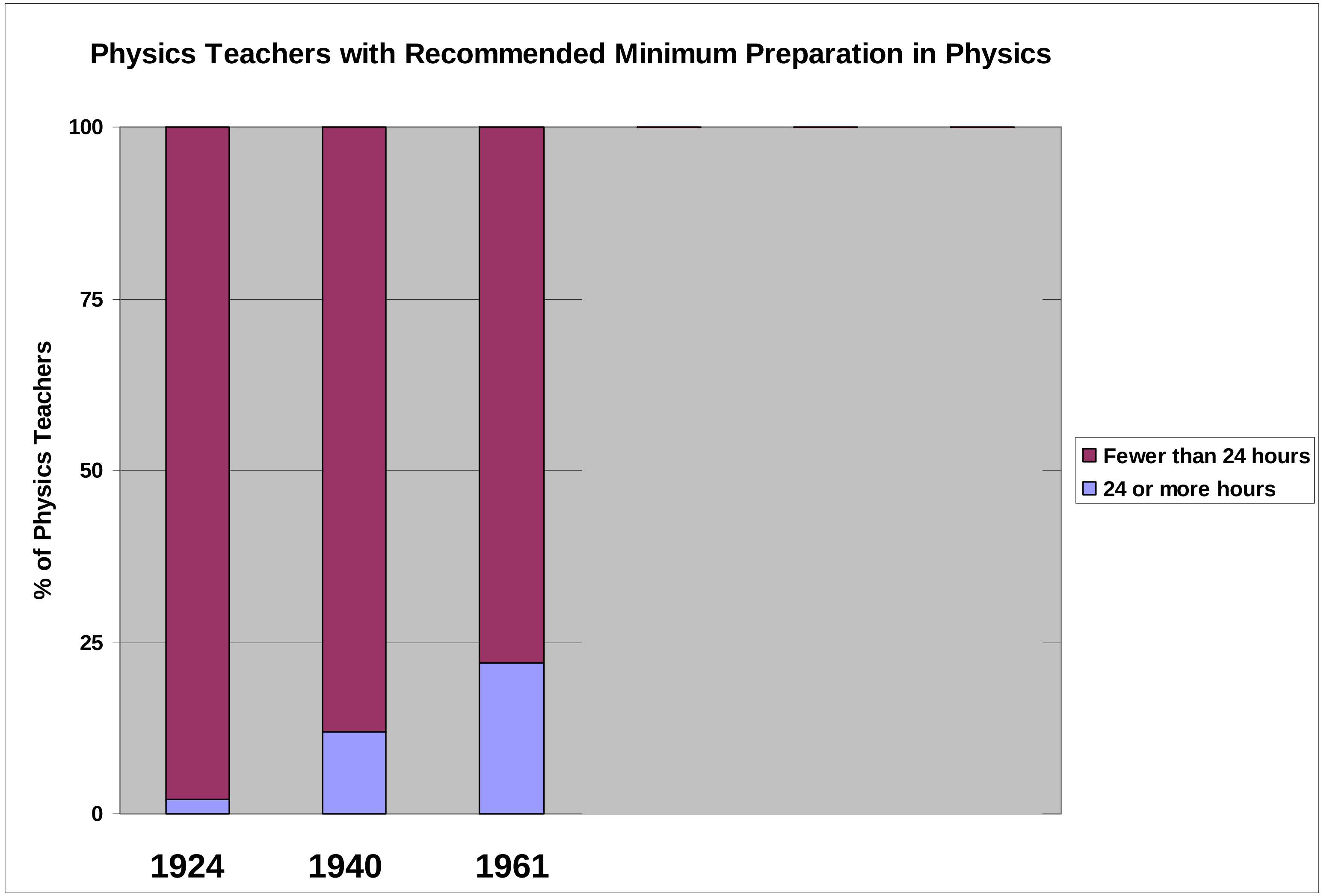

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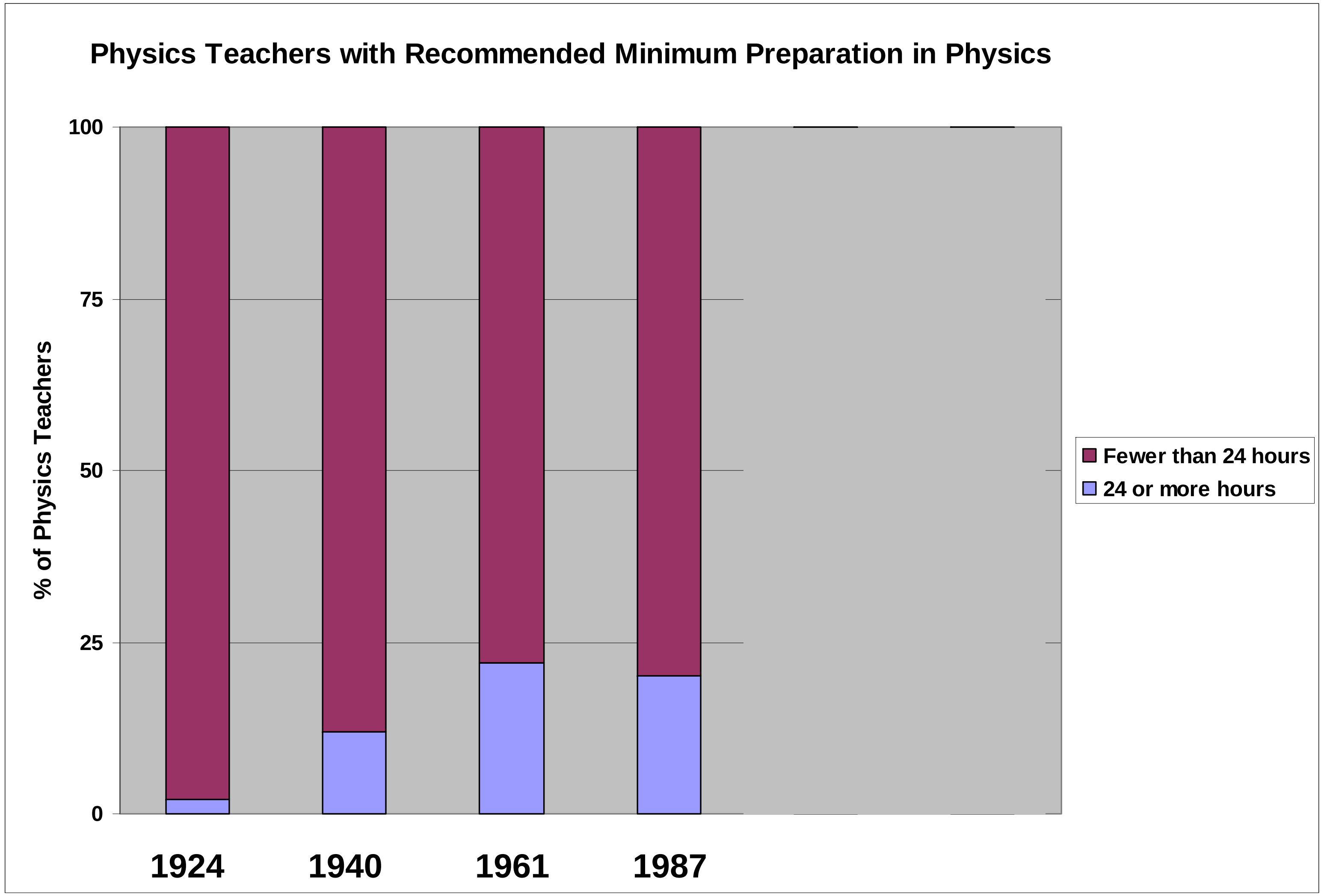

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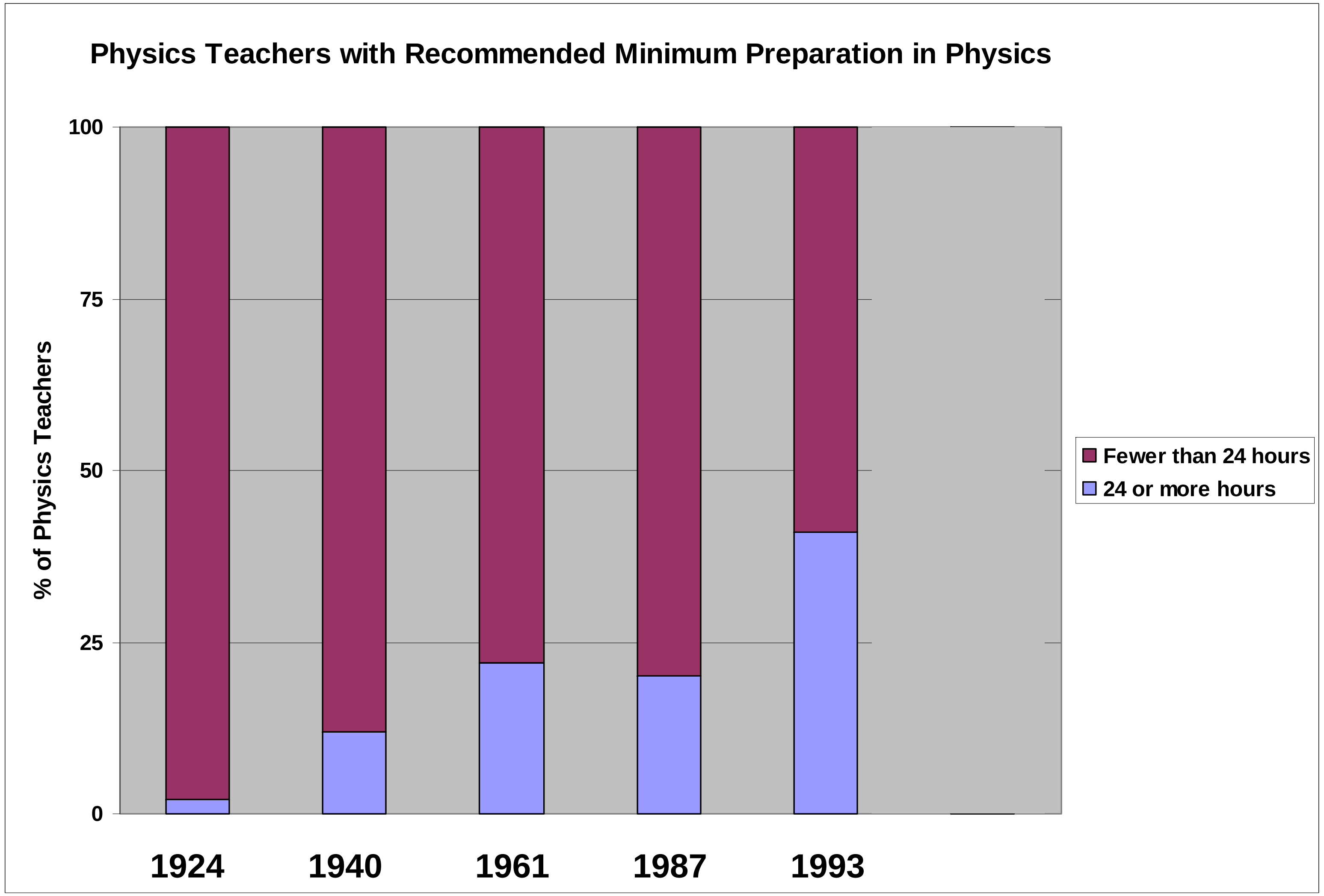

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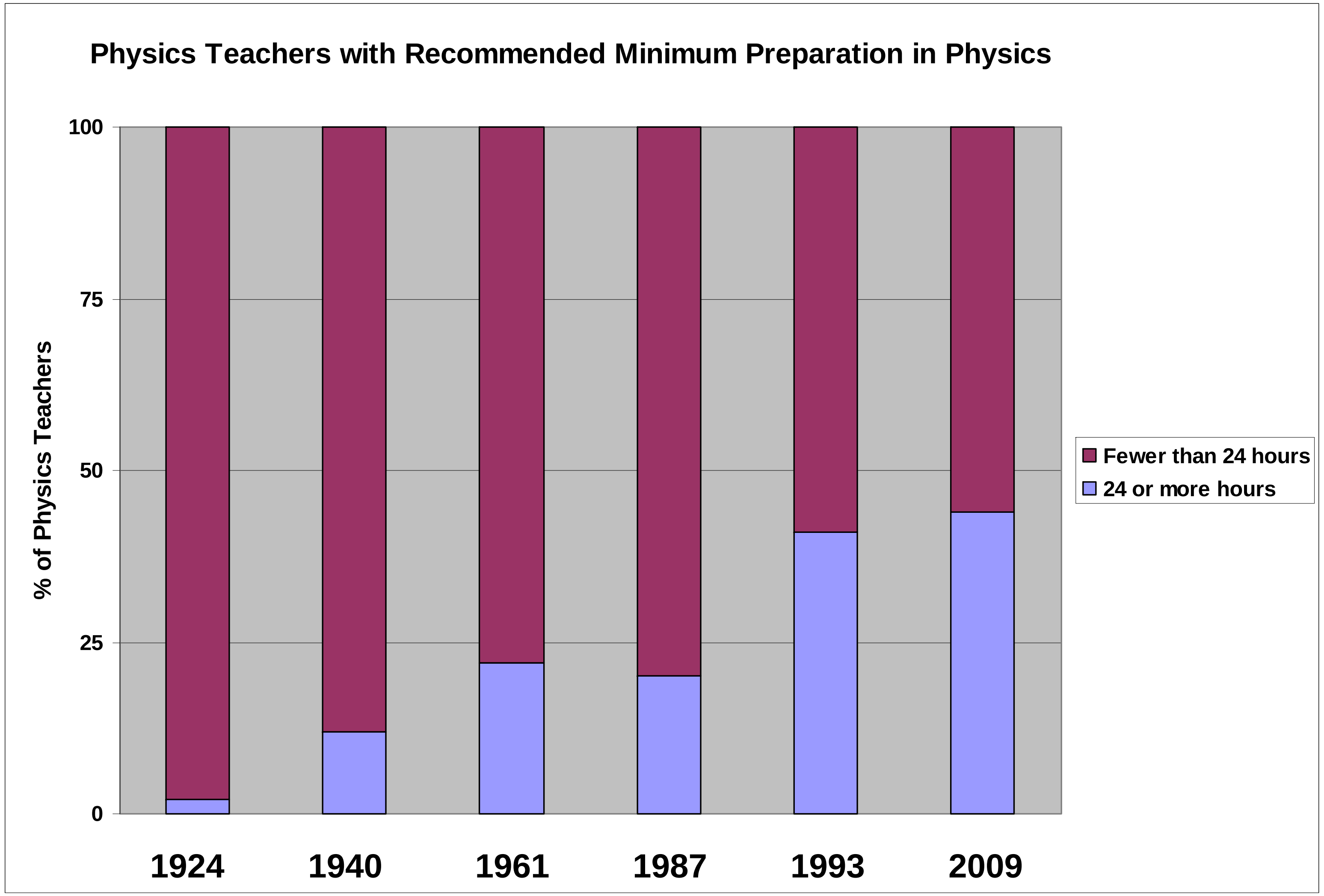

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Does a Teacher's Physics-Major Background Make a Difference?

Hughes (1925) compared students' performance on a common physics test for four groups of teachers:

- **I:** no college physics
- **II:** one year of college physics
- **III:** two years of college physics
- **IV:** with physics major

(Note: No significant differences in students' IQ or years of teaching experience among the four groups)

Does a Teacher’s Physics-Major Background Make a Difference?

Result:

- Students with highest test scores had teachers who had completed a physics major

- Students whose teachers had one or two years of college physics did (slightly) worse than those who teachers had no college physics

[J.M. Hughes, School Review **33**, 292 (1925)]

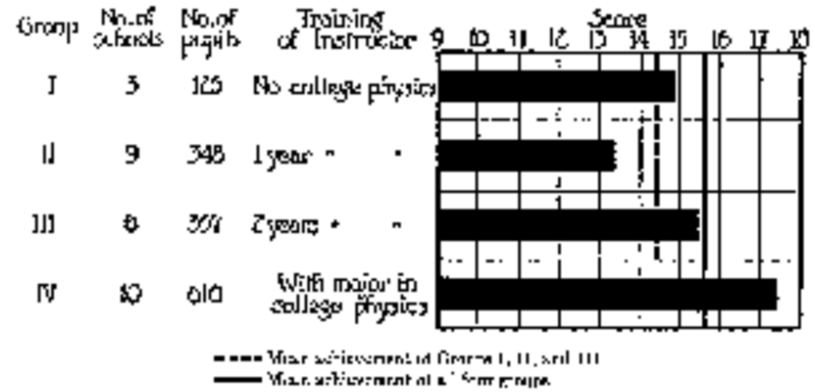


FIG. 9.—Comparison of mean achievements on tests in mechanics and heat of pupils taught by teachers with varying amounts of training.

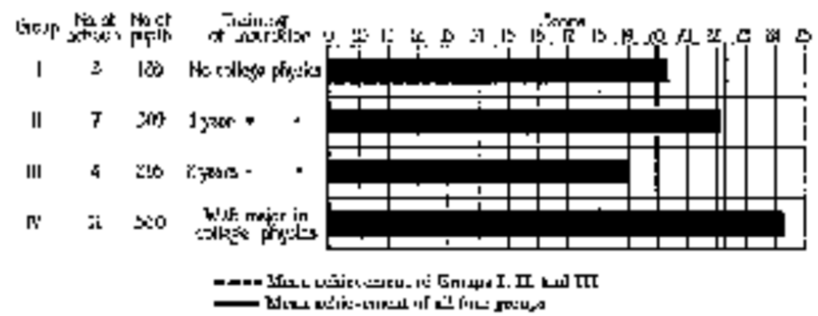


FIG. 10.—Comparison of mean achievements on tests in magnetism and electricity of pupils taught by teachers with varying amounts of training.

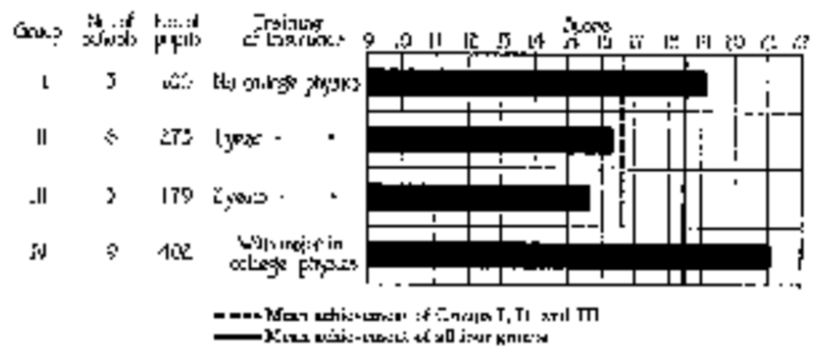
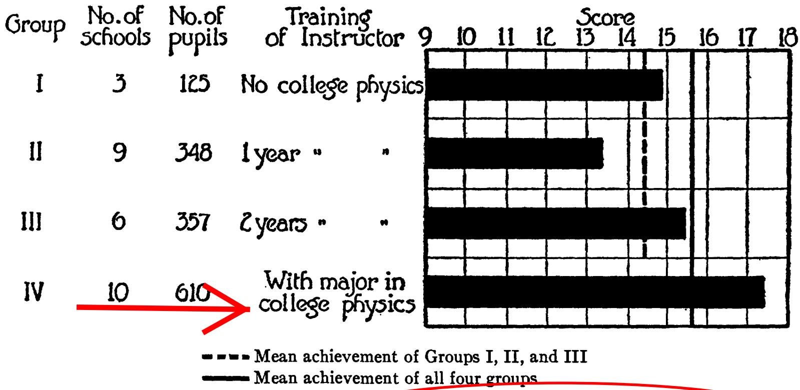


FIG. 11.—Comparison of mean achievements on tests in sound and light of pupils taught by teachers with varying amounts of training.



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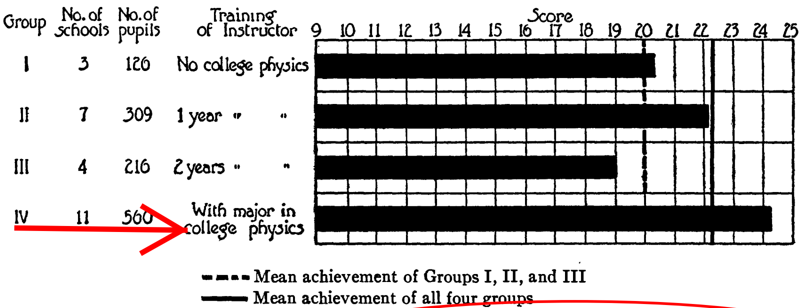

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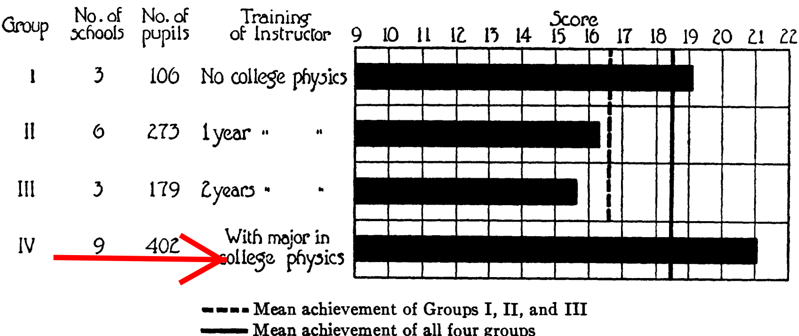

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2. Research in Physics Teacher Education: A Fundamental Obstacle

Teacher Preparation: Research vs. Practice

- Efforts to improve teacher preparation are treated as practical, applied problems incorporating “art and design”
- Focus is on overall program change, not on close examination of individual program elements
- Assessment and evaluation—such as there is—tends to be on broad program measures

“Practical” Approach to Course and Program Development

- Multiple elements of courses or programs are simultaneously introduced or revised
    - Revisions are based on practical experience, interpretations of the literature, plausible hypotheses, etc.
    - Revisions tend to be ongoing, and mutually influencing
- Documentation of changes in practice or outcomes is often haphazard or superficial

What are the Objects of Investigation?

- With few exceptions, research focuses on entire programs, not on individual programmatic elements
  - ➢ Elements in *one specific* program may be examined, but not common elements across multiple diverse programs
- Common themes emerge, reflecting:
  - ➢ Program characteristics
  - ➢ Outcomes considered significant

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Some Historical Highlights

- 1920s: Investigation of link between physics teacher preparation and student performance
- 1920s-present: Surveys of physics teachers’ preparation
- 1950s-60s: Reports of summer institutes of physics teachers
- 1970s: Reports of research-based courses for physics teachers
- 1980s-present: Reports of research-based physics teacher education programs

Research on Summer Institutes for Physics Teachers: 1940s-1960s

- Summer workshops for inservice physics teachers began in the 1940s
- Initially supported by private industry
- NSF support began in early 1950s
- Rapid expansion in funding beginning in 1956, explosion in funding starting in 1957
- PSSC curriculum developed and disseminated beginning in 1958-1960
- “Project Physics” curriculum developed and disseminated 1970s-1980s

First Evaluation of Institutes: Olsen and Waite (1955)

- Evaluation of eight years (1947-1954) of six-week summer institutes for physics teachers (50 per summer) sponsored by General Electric Corporation, held at Case Institute of Technology
- Questionnaires received from 60% of all former participants
- 50% of these report improved attitude or enthusiasm
- Dramatic increase in enrollment at Case of students of these institute participants (0→45), with above-average scores on pre-engineering "ability test"

Evaluation of NSF-Supported Summer Institutes (PSSC and Project Physics): Welch and Walberg (1967, 1972)

- Participants at four 1966 summer institutes made “significant gains” in understanding of physics content

➢ *However, note this comment by the Physics Survey Committee of the National Research Council (1973):* “The gains in mean scores…were…so slight that it is doubtful that any long-term effects exist. There also is considerable anecdotal evidence…that summer institutes are often presented at the same breakneck speed that contributes to the necessity for them in the first place.”

- Students of teachers who participated in six-week 1972 summer institute focused on Project Physics reported significantly higher degrees of course satisfaction in comparison to a control group of students whose teachers who taught only “regular” physics

3. Common Themes in Recent Research (1970-present)

Common Themes in Research on Physics Teacher Education

- Physics teachers or preservice teachers often underestimate and/or do not address their students' ideas and "alternative conceptions" in physics.
- Preservice and in-service physics teachers value and require close and extended supervision by expert physics teachers as they plan and implement structured lab activities.
- *Outcomes:* Special courses on physics concepts and pedagogy for teachers have often been shown effective in improving their physics understanding and/or teaching practices, as well as their students' learning.

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Teachers Tend to Underestimate or Mischaracterize Students' Ideas

- Canadian physics teachers consistently underestimated prevalence of specific alternative conceptions among their students. [Berg and Brouwer, 1991]
- Dutch, Portuguese, and Swedish preservice teachers were more likely to expect their students to have specific conceptual problems when they had overcome those same conceptual problems themselves. [Frederik et al., 1999]
- Many Malaysian student teachers did not address their students' common incorrect ideas, even when they were aware of them. [Halim and Meerah, 2002]
- U.S. pre- and in-service teachers enrolled in a course for future teachers initially guessed at students' ideas based on "intuition"; those students with *weaker* physics background progressed toward understanding actual documented students' ideas [Thompson, Christensen, and Wittmann, 2011]

Common Themes in Research on Physics Teacher Education

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Teachers Benefit from Coaching by Experts while Designing and Implementing Lab Investigations

- Pre- and In-service teachers experience multiple, extended opportunities to analyze physical systems, and make and test predictions, by developing and reflecting on laboratory-based physics activities, and examining students' ideas about these systems [Niedderer & Schecker, 1997; Jauhianen et al., 2002; Kriek and Grayson, 2009; Etkina, 2010; Nivalainen et al., 2013]
- These activities often form the basis of laboratory investigations that are taught by the teachers, either in "micro-teaching" or in actual classrooms [Thomaz and Gilbert, 1989; Messina et al., 2005; Sperandeo-Mineo et al., 2006; Mikelsis-Seifert & Bell, 2008; Etkina, 2010]

Common Themes in Research on Physics Teacher Education

- *Outcomes:* Special courses on physics concepts and pedagogy for teachers have often been shown effective in improving their physics understanding and/or teaching practices, as well as their students' learning.

Outcomes Frequently Reported

- Improved understanding of physics content knowledge, and *confidence* in their knowledge, by pre- and in-service teachers enrolled in courses and summer institutes designed for teachers [Many sources]
- Improved learning by *students* of teachers who participated in research-based physics teacher education programs
- Better awareness of students' ideas about physics and other elements of "pedagogical content knowledge" in physics
- Greater use of classroom practices that are consistent with research-based instruction

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Third-Party Evaluation of Research-Based Physics Teacher Education Programs

- NSF contracted a study carried out in 1999 by TIMSS [Third International Mathematics and Science Study].
- The study assessed performance on the TIMSS physics test by students taught by teachers who had participated in NSF-sponsored teacher enhancement and physics material development programs.
- Students taught by teachers in NSF-sponsored programs performed significantly better than a broad sample of all U.S. 12th-grade physics students.
- Among the programs included in the study: Arizona State University, San Diego State University; University of Washington

Additional Evidence to Corroborate TIMMS Study

- **Arizona State University:** Students of teachers who participated in “Modeling Workshops” consistently show better performance on the Force Concept Inventory [mechanics diagnostic test] than students of teachers who had not been through that or any comparable program. [Wells, Hestenes, and Swackhamer, 1995; Hake, 1998; Hestenes et al., 2011]
- **University of Washington:** Students of teachers who participated in “Physics by Inquiry” activities on light had much higher post-instruction scores on diagnostic tests covering the material (45%) than undergraduate university physics students taking the same tests (20%). [McDermott et al., 2006]
- **San Diego State University:** Students of teachers who participated in “Constructing Physics Understanding” workshops had 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. [Huffman et al., 2003; Huffman, 2006]

Outcomes Frequently Reported: Improved Knowledge and Practice of Teaching

- Better awareness of students’ ideas about physics and other elements of “pedagogical content knowledge” in physics
- Greater use of classroom practices that are consistent with research-based instruction

Outcome: Knowledge and Practice of Teaching

- [Spain, Britain] Preservice teachers analyzed common pitfalls in physics problem-solving; improvements in their problem-solving strategies were observed. [Garrett et al., 1990]
- [Italy] Student teachers developed and tested new physics lab experiments based on analysis of student-learning data. They progressed from mere "verification" experiments to modeling experiments aimed at generating coherent explanations of observed phenomena. [Aiello-Nicosia and Sperandeo-Mineo, 2000]
- [United States] Program participants' knowledge of science processes (such as experiment design) underwent dramatic improvements over the course of the program. [Etkina, 2010]

Outcome:
Knowledge and Practice of Teaching

- [Germany] Intervention group teachers participated in multiple cycles of coaching with video analysis followed by post-reflection; the students of these teachers were observed to act increasingly "autonomously" [rather than "recipe-like"] over the course of the intervention. [Wackermann et al., 2010]
- [United States] Former program participants implemented science teaching practices more closely aligned with national science teaching standards than did teachers in a comparison group. [Gray, Webb, and Otero, 2016]
- [Finland] Pre-service teachers allowed to freely define problems and select laboratory procedures became much better aware of physics teachers' pedagogical knowledge over the period of the study. [Nivalainen et al., 2013]

Summary

- There are very few rigorous investigations of specific elements of physics teacher education programs;
- Instead, one must look to commonly reported program features and commonly observed program outcomes.
- Reported outcomes suggest that physics teachers in research-based education programs gradually become comfortable in applying the outlooks and practices of physics, and become more able to guide students in inducing physical principles from observational data [McDermott, 1975; 1990].
- Going forward, physics teacher educators could benefit from more narrowly focused investigations of specific features of education programs.

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