Common Themes and Outcomes in Research-Based Physics Teacher Education

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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 are—tend to be on broad program measures.

- 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 practices or outcomes is often haphazard or superficial
- 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**

Common Themes in Research on Physics Teacher Education

1. Physics teachers or preservice teachers often underestimate and/or do not address their students' ideas and "alternative conceptions" in physics.
2. 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.
3. *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.

1. 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 backgrounds progressed toward understanding actual documented students' ideas, but "stronger" students did not. [Thompson, Christensen, and Wittmann, 2011]

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

- Pre- and in-service teachers benefit by experiencing multiple, extended opportunities to analyze physical systems, and make and test predictions, by developing and reflecting on laboratory-based physics activities, and by 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]

3. Outcomes Frequently Reported

A. 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]

B. Improved learning by *students* of teachers who participated in research-based physics teacher education programs

C. Better awareness of students' ideas about physics and other elements of "pedagogical content knowledge" in physics

D. Greater use of classroom practices that are consistent with research-based instruction

Outcome B: Improved Learning by Students

- 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 U.S. 12^{th}-grade physics students.
- Among the programs included in the study: Arizona State University, San Diego State University; University of Washington; all of these programs published *separate*, corroborative studies showing improved student learning.

Outcome D: Greater Use of Research-Based Classroom Practices

- [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]
- [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]
- [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]
- [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]