Evidence-Based Instruction in Physics Teacher Education

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Abstract

- There has been relatively little published research examining evidence on the effectiveness of physics teacher education programs in the United States. One reason for this is that such research is neither strongly encouraged nor substantially supported by U.S. funding agencies. Outside the U.S., physics teacher education programs tend to be more thoroughly integrated into the normal academic practices of disciplinary departments, and so publication of such research results is more common. [See D. E. Meltzer, “Research on the education of physics teachers,” in *Teacher Education in Physics: Research, Curriculum, and Practice*, edited by D. E Meltzer and P. S. Shaffer (American Physical Society, College Park, MD, 2011), pp. 3-14.]

- I will review some of the highlights of research on physics teacher education done outside the U.S.

Research on Courses for Physics Teachers Outside the U.S.

- Outside the U.S., physics departments and/or education colleges often have special programs targeted at preparation of high school physics teachers. Such programs typically include one or more courses focusing explicitly on pedagogy of physics teaching, often in a practical (laboratory) setting.
- Published reports of courses for physics teachers often, but not always, include assessment or evidence of changes in students' physics knowledge, pedagogical ideas, or attitudes towards teaching.
- Here we will present representative examples of reports on courses for physics teachers, in chronological order.

Research on Courses for Physics Teachers Outside the U.S.

- C. Hernandez and A. Rushby, “A new course for physics teachers in Peru,” Phys. Teach. **11**, 401-405 (1973). Students design, construct, and discuss demonstration experiments.
- A. A. Chen, “A course for physics teachers in Jamaica,” Phys. Teach. **13**, 530-531 (1975). Focuses on ways to teach concepts that are difficult to teach and easily misunderstood. Students give lecture-demos to freshman on “physics and everyday life” topics.
- P. Thomsen, “A new course in electricity and magnetism for education of physics teachers,” in *Seminar on the Teaching of Physics in Schools 2: Electricity, Magnetism and Quantum Physics* (Gyldendal, Cophenhagen, 1975), pp. 120–150. New course that closely integrated experiment and theory was tested successfully with pre-service and in-service teachers in Denmark.

Research on Courses for Physics Teachers Outside the U.S.

- R. M. Garrett, D. Satterly, D. Gil Perez, and J. Martinez-Torregrosa, “Turning exercises into problems: An experimental study with teachers in training,” Int. J. Sci. Educ. **12**, 1–12 (1990). Preservice teachers in Spain and Britain analyzed common pitfalls in physics problem-solving and their implications for more effective teaching strategies; improvements in their problem-solving strategies were observed.

- H. Niederrer and H. Schecker, “Laboratory tasks with MBL and MBS for prospective high school teachers,” in AIP Conference Proceedings **399**, 461–474 (1997). Special *introductory* physics course for undergraduate German preservice teachers: students work out their own predictions and explanations, listen to instructor’s comments, then devise and execute experiments to compare with theory.

- T. Ryu, “Various methods of science teaching: An example of a preservice course from Sophia University,” in AIP Conference Proceedings **399**, 699-707 (1997). Course in physics teaching for Japanese physics and chemistry undergraduates: students do experiments, listen to experienced high school teachers, and compare science curricula from different countries.

Research on Courses for Physics Teachers Outside the U.S.

- L. Aiello-Nicosia and R. M. Sperandeo-Mineo, “Educational reconstruction of physics content to be taught and of pre-service teacher training: a case study,” Int. J. Sci. Educ. **22**, 1085–1097 (2000). Post-graduate student teachers in Italy who were math majors develop and test new physics lab experiments, based on their analysis of actual student-learning data during a 12-hour workshop. They progressed from initially seeking mere “verification” experiments to instead developing and appreciating modeling experiments that aimed to generate coherent explanations of observed phenomena.

- J. Kriek and D. Grayson, “Description of a course for secondary school physics teachers that integrates physics content & skills,” in *What Physics Should We Teach? Proceedings of the International Physics Education Conference, Durban, South Africa* (ICPE, 2005), pp. 185-190. In-service teachers in South Africa are guided to make predictions about systems, carry out experiments to test their predictions, and generate explanations for the observations.

- M. A. Asikainen and P. E. Hirvonen, “A study of pre- and inservice physics teachers’ understanding of photoelectric phenomenon as part of the development of a research-based quantum physics course,” Am. J. Phys. **77**, 658–666 (2009). A course using research-based active-learning instruction improved understanding of the photoelectric effect among Finnish preservice and in-service physics teachers.

Research on Courses for Physics Teachers Outside the U.S.

- A. De Ambrosis and O. Levrini, “How physics teachers approach innovation: An empirical study for reconstructing the appropriation path in the case of special relativity,” Phys. Rev. ST - Phys. Educ. Res. **6**, 020107-1–11 (2010). Italian in-service teachers carried out detailed analysis of various curricular materials on special relativity from the standpoint of how to teach them effectively in high school.
- V. Nivalainen, M. A. Asikainen, and P. E. Hirvonen, “Open guided inquiry laboratory in physics teacher education,” J. Sci. Teacher Educ. **24**, 449-474 (2013). Finnish pre-service teachers are allowed to freely define problems and select laboratory apparatus and procedures after being given only the main topic to be developed into a high school teaching unit. Results indicate that students become much better aware of physics teacher’s pedagogical knowledge.

Research on Physics Teachers' Knowledge of Teaching

1. Documentation of Physics Teachers' Ideas About Physics Pedagogy
2. Investigating Teachers' Knowledge of Students' Ideas
3. Developing and Assessing Physics Teachers' Pedagogical Content Knowledge

Documentation of Physics Teachers' Ideas About Physics Pedagogy

- J. Loughran, A. Berry, and P. Mulhall, *Understanding and Developing Science Teachers' Pedagogical Content Knowledge* (Sense Publishers, Rotterdam, 2006), Chaps. 7 and 8.
  - choose a specific topic (e.g., "Forces") and then gather together a group of experienced teachers who begin by generating a set of "Big Ideas" for this topic (e.g., "The net force on a stationary object is zero").
  - The teachers then collaborate to provide responses to such questions as:
    - What do you intend the *students* to learn about this idea?
    - What are difficulties/limitations connected with teaching this idea?
    - What knowledge about students' thinking influences your teaching of this idea?
    - What are some teaching procedures/strategies (and particular reasons for using these) to engage with this idea?
    - What are specific ways of ascertaining students' understanding or confusion around this idea?

Investigating Teachers' Knowledge of Students' Ideas

- T. Berg and W. Brouwer, "Teacher awareness of student alternate conceptions about rotational motion and gravity," J. Res. Sci. Teach. **28**, 3–18 (1991). Canadian physics teachers consistently underestimated prevalence of specific alternative conceptions among their students.
- I. Frederik, T. van der Valk, L. Leite, and I. Thorén, "Preservice physics teachers and conceptual difficulties on temperature and heat," Eur. J. Teach. Educ. **22**, 61–74 (1999). Dutch, Portuguese, and Swedish perservice teachers were more likely to expect their students to have specific conceptual problems when they had overcome those same conceptual problems themselves.
- L. Halim and S. M. Meerah, "Science trainee teachers' pedagogical content knowledge and its influence on physics teaching," Res. Sci. Tech. Educ. **20**, 215–225 (2002). Many Malaysian student teachers did not address their students' common incorrect ideas, even when they were aware of them.

Developing and Assessing Physics Teachers' Pedagogical Content Knowledge

- D. Nachtigall, "Physics teacher education in Dortmund," Phys. Teach. **18**, 589–593 (1980). Small groups of German preservice teachers worked together to solve, discuss, and present problems. Problem tasks included analyzing students' alternative conceptions, and explaining physics terms and concepts at a high-school level.
- M. F. Thomaz and J. K. Gilbert, "A model for constructivist initial physics teacher education," Int. J. Sci. Educ. **11**, 35–47 (1989). Small groups of Portuguese preservice teachers planned a structured lab lesson/activity and practiced teaching it to high school students. Later, the teachers "practice-taught" under normal classroom conditions. It was found that close, patient supervision by expert physics-teacher educators was necessary for success.
- J. Jauhiainen, J. Lavonen, I. Koponen, and K. Kurki-Suonio, "Experiences from long-term in-service training for physics teachers in Finland," Phys. Educ. **37**, 128–134 (2002). Finnish teachers in a long-term in-service training program valued most highly a course in which they planned, tested, and implemented structured lab experiments with a conceptual theme.

Developing and Assessing Physics Teachers' Pedagogical Content Knowledge

- R. M. Sperandeo-Mineo, C. Fazio, and G. Tarantino, "Pedagogical content knowledge development and pre-service physics teacher education: A case study," Res. Sci. Educ. **36**, 235–269 (2006). Italian in-service teachers, guided closely by experienced physics educators, carried out laboratory investigations and developed and analyzed teaching and learning sequences for use in high school classes. Their ability to communicate the targeted physics ideas improved substantially.

- S. Mikelskis-Seifert and T. Bell, "Physics in Context—Teacher professional development, conceptions and findings of evaluation studies," in *Four Decades of Research in Science Education (*2008), pp. 221–238. Groups of ten German in-service teachers were coached by a physics educator on a long-term basis. The coaches' inputs were only useful when also accompanied by intensive coaching during development of new teaching materials.

- R. Wackermann, G. Trendel, and H. E. Fischer, "Evaluation of a theory of instructional sequences for physics instruction," Int. J. Sci. Educ. **32**, 963–985 (2010). German in-service teachers received lesson-coaching from physics educators. Video analysis and post-reflection discussion were based on a specific model of the learning process, emphasizing problem solving and concept building. Significant changes were observed in teachers' subjective beliefs and classroom actions.

Developing and Assessing Physics Teachers' Pedagogical Content Knowledge

- J. Riese and P. Reinhold, "Measuring physics student teachers' pedagogical content knowledge as an indicator of their professional action competence," in *Contemporary Science Education Research: Teaching* (ESERA, 2010), pp. 79-85. A new instrument to measure German teachers pedagogical content knowledge was developed and tested.
- J. Olszewski, K. Neumann, and H. E. Fisher, "Measuring physics teachers' declarative and procedural PCK," in *Contemporary Science Education Research: Teaching* (ESERA, 2010), pp. 87-94. Describes yet another instrument to measure German teachers pedagogical content knowledge; in early stages of testing.