Teaching as They Were Taught: The Importance of Reformed University Courses

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The following comment is from a preservice physics teacher who was reflecting on his experiences in a high-school physics classroom:

> In [the field experience] classroom this week, I was surprised by the significant lack of "lecturing", instead having short explanations followed by the students working on problems amongst themselves. On the surface, in the conscious part of my mind, this was a wildly different way of teaching, compared to what I saw as the standard paradigm of science instruction. But deep in my mind, I knew that this was the "right" way to teach; let the students learn by doing. As I sat writing this paragraph, I put it all together and realized why. Because in research science, the paradigm is working through the problems, struggling with the concepts, but when it all comes together, it's like daylight. The standard teaching paradigm I'm so used to from many years as a student is the teacher lectures, and then we do simple homework, and confirmatory labs. I was finally seeing science teaching being done like science, and that's why I knew deep down that it was "right".

A Call for Reform

This preservice teacher was clearly struggling with the contradiction between how he was taught science, and how science was being taught in this high-school classroom. This is exactly the type of questioning that is critical to the development of a competent physics teacher. However, far too few preservice and beginning teachers struggle with these issues, and fall back into a "teaching as they were taught" mode (Carter & Doyle, 1995; Anderson, et al., 1995). And, given all the evidence from physics education research that exposure to traditional instruction does little to impact conceptual understanding of physics, preservice teachers leave these traditional physics courses with a limited understanding of the content. In addition, many preservice physics teachers are exposed to interactive or inquiry-based teaching techniques in only one or two education methods courses, which does little to ameliorate their years of exposure to traditionally presented physics content. Thus, the role of physics courses in preparing physics teachers should not be underestimated.

Beginning with *A Nation at Risk* (National Commission on Excellence in Education, 1983) through *Shaping the Future* (National Science Foundation, 1996), and recently with *To Touch the Future: Transforming the Way Teachers are Taught* (American Council on Education, 1999), reports published in the USA have decried the inadequate preparation and lack of competency of new science teachers at all levels, and called for the reform of ineffective and antiquated teacher preparation programs. The reports cite inadequate understanding of science content (physics, in particular) and the lack of student-centered, inquiry-based approaches in science classrooms. Further, these reports provide "clear and convincing evidence that the single most powerful factor in student achievement gain is the quality of the teacher" (American Council on Education, 1999). It is clear then, that the "reform of ineffective and antiquated teacher preparation programs" must include reform of the physics content courses in which prospective teachers enroll.

Answering the Call

As John Layman more fully describes in his contribution to Round Table 2 (*University, Schools, Teachers: Cooperative Relationships*), in response to this call for improvement in teacher preparation in the USA, three professional societies have joined together to support and promote reform at selected institutions throughout the country. The Physics Teacher Education Coalition (PhysTEC) is a joint project of the American Physical Society, the American Association of Physics Teachers, and the American Institute of Physics. Funded by the National Science Foundation, the US Department of Education, and corporate donations, PhysTEC supports reform at six primary program institutions (PPIs) that have all agreed to implement a set of core reforms designed to improve the physics preparation of future science teachers.

The key aspect of PhysTEC-supported reform that addresses the issues presented here is the redesign of content and pedagogy for targeted physics courses, based on results from physics education research and utilizing appropriate interactive technologies. This reform is intended to improve students' conceptual understanding of physics and make it more likely that they will "teach as they were taught" in their future classrooms. In addition, faculty members at the PPIs are involved in the redesign of content and pedagogy for elementary and secondary science methods courses with an emphasis on inquiry-based, hands-on approaches to teaching and learning.

Changes at the PhysTEC PPIs

There are currently six institutions from throughout the USA who are primary program institutions of PhysTEC—Ball State University (Muncie, Indiana), Oregon State University (Corvallis, Oregon), University of Arizona (Tucson, Arizona), University of Arkansas (Fayetteville, Arkansas), Western Michigan University (Kalamazoo, Michigan), and Xavier University (New Orleans, Louisiana). Over the past two years, faculty at these institutions, in collaboration with secondary-school physics "Teachers in Residence" have begun reform of both physics and science methods courses.

A key aspect of the reform of courses at several of the PPIs that have large-enrollment classes is the use of electronic response systems that allow students to signal their answers to multiple-choice questions posed during the lectures (Burnstein & Lederman, 2003). Faculty members at these PPIs are developing libraries of conceptual questions designed to be used with these systems. These questions require students to discuss their ideas with each other, and allow the instructors to gauge students' understanding of the material just presented. The peer interaction also helps address students' misconceptions.

Another aspect of course reform is the re-design of physics laboratories, moving away from "cookbook-style" confirmatory labs and toward more inquiry-based labs. Students are guided in posing their own questions, designing their own procedures, and analyzing their data, but are not told ahead of time what results they should obtain. In addition, these reformed labs are designed so that students experience "thinking like a physicist." It is important to note that these reforms in both lecture and laboratory benefit all students in the courses, not just the prospective teachers.

Some of the PPIs are developing specialized physics courses for prospective elementary teachers. These courses are based on research-based curricula such as *Powerful Ideas in Physical Science* (American Association of Physics Teachers, 2002), which are designed to engage students in meaningful science activities that they can eventually use with their own students.

Several of the PPIs have specialized physics methods courses for prospective secondary school physics teachers. These courses focus on the implementation of inquiry-based teaching methods in the physics classroom, use of lab equipment and technology, examination of existing curricular materials, and practical issues such as lab safety, classroom management, and grading student work. Many of these courses are team-taught by faculty members from physics and education, along with the Physics Teachers in Residence.

All of these course modifications are continually evaluated and adjusted at each of the PPIs. In addition, all of the PPIs are tracking students' conceptual understanding with the use of Force Concept Inventory (Hestenes, Wells, & Swackhamer, 1992) and the Conceptual Survey of Electricity and Magnetism (Maloney, O'Kuma, Hieggelke, & Van Heuvelen, 2001). Early results from these instruments indicate that the course reforms are leading to gains in conceptual understanding. Preservice teachers' are also completing the Attitudes and Beliefs about the Nature of and Teaching of Mathematics and Science Instrument (McGinnis, et.al., 2002) to track the evolution of their beliefs about teaching and learning.

At this point, only a small number of students have completed their teacher preparation programs at any of the PPIs, and so it is too early to be able to determine if the reform of these courses has had an impact on their teaching. However, if teachers "teach as they were taught," we cannot expect them to use interactive and inquiry-based methods if they have never experienced them as students. Thus, these reforms should result in better physics teaching for future generations of pre-college students.

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