

**Testimony in the Hearing on PACE Act Teachers- 2/28/06**  
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Among the many factors that contribute to the current alarming state of pre-college science education in the US, as indicated by the poor performance in science test scores and students' low interests in pursuing science and technology related careers, is the quality of teachers teaching science in pre college education. A major reason for the concern of teacher quality is the lack of content preparation of science, and likewise math, teachers.

Many anecdotal examples provided by students show that many students attribute their lack of interests in science to a bad teacher once in their learning experience. The reverse is equally true: A good teacher at one point during their learning may inspire interest and more importantly instill confidence in students' dealing with challenging and abstract subjects. A teacher who can teach and inspire has to be confident in the subject he/she is teaching. Without sufficient content knowledge, a teacher can hardly possess such confidence.

For short of content-prepared teachers, 'teaching out of field' has been identified by the education community (see works by Richard Ingersoll, Graduate School of Education, University of Pennsylvania) as an increasingly problematic and important practice in math and science education within the last decade in American high schools. A casual survey of the 80 or so freshman at the University of Pennsylvania in 2004 and 2005 who intended to major in Chemistry and Biochemistry showed that nearly all of them had taken AP chemistry in high school but nearly half of them were taught by teachers whose original subject of expertise were not chemistry. Often it was biology. One should note that most of these students came from schools/school districts that were deemed successful.

In 1999, a survey conducted by Penn's Department of Chemistry found that in the Philadelphia School District, a large urban school district with more than 200,000 students, there were only 37 chemistry teachers. Of these teachers, about half did not have chemistry as major in college.

A significant reason for allowing teachers who do not have sufficient content training to teach hardcore science courses is the unique American education philosophy, championed by the famous education philosopher John Dewey, that how one teaches is more important than what one teaches. A consequence of this philosophy materialized in education practice is that teacher certification requires pedagogy training but not necessarily content training.

The other major practice that has led to the lack of content requirement in teacher certification, in the view of this observer who was born and educated through college abroad, is that in the US K-12 education is a local/state matter. In most other countries K-12 education is a central government concern that involves institutions of higher

education in matters related to setting curricular and standards, and thus also requirements of teacher certification. It is hard to imagine similar practices happen in local school boards involving institutions of higher education.

The State of Pennsylvania only recently established the content requirements on science teacher certification. But even this new requirement appears to be relatively inadequate in comparing with teacher certification requirements in many countries in Asia and Europe. In Pennsylvania, to be a secondary school science teacher requires 27 credit hours of study in the discipline area in college. To be a middle school science teacher requires taking only 10 credit hours of science courses in college. Basically, any students who have taken only 3 basic science courses and a laboratory may satisfy this requirement. By comparison, in Taiwan, where I grew up, and Singapore, whose students consistently scored the best in the world, a science teacher has to major in a science subject in college with an additional year of pedagogy training. A BS in science in these countries usually requires at least 70 credit hours study on science subjects. A BS degree in these countries, like in Germany and some other European countries, amounts to a master degree in the US.

Many mechanisms have been set up to address the problem of the lack of content knowledge in science teachers. Many workshop and short-course type programs have been conducted by professional societies, institutions of higher learning, and even industries to address specific content issues that may have been encountered by teachers in teaching. These activities would be highly valuable, should the participating teachers already have a solid base in content knowledge on the subject they teach. Such solid base in content knowledge can be best acquired through organized learning in a degree program.

In 2000, the Chemistry Department at the University of Pennsylvania, in collaboration with the Graduate School of Education, launched a new Master of Chemistry Education degree program for training 20 in-service science teachers each year. This program is designed with the following features:

- 1) The 10 courses in the curriculum emphasize chemistry content (8 courses) and pedagogy in science education (2 courses).
- 2) Full scholarship is provided for relieving the financial burden of participating in-service teachers.
- 3) The classes are conducted over 26 months: three summers (full time, each summer 2 courses) and two academic years (alternating Saturday mornings, 2 courses per academic year) so not to interfere in-service teacher job functions.
- 4) All courses are specifically designed for teachers. Science content is presented along with up-to-date technology. Importance of science and technology to society and humanity is included. Science content is blended in with inquiry-based teaching methods in almost all courses.
- 5) A cohort system is used and a teacher resource center established to provide support for learning of the teachers and implementing reforms in their own classrooms.

This program has been supported primarily by scholarships provided by Penn, donations from local industry (such as Rohm and Hass), and a seed grant from the National Science Foundation.

In 2005, with substantial new funding from the NSF through the Math and Science Partnership Program, the Penn Science Teacher Institute was established with the continuing MCE program and a new Master of Integrated Science Program aimed at training in-service middle school science teachers. The latter program involves courses offered in Biology, Environmental and Earth Sciences, Mathematics, and Physics, in addition to Chemistry and Science Education. Now every year, 40 new teachers are trained through these programs.

Teachers' response to these programs as a form of professional training has been very enthusiastic. Many teachers do recognize the importance of content preparation and are willing to commit major effort and time to gain this content knowledge. Many teachers drove hours from central Pennsylvania, Northern Jersey, and Maryland to attend classes. One teacher from Oregon even took sabbatical time and summers to complete the degree. After 6 cohorts (120 chemistry teachers admitted), the MCE program still has a 2-1 application to admission ratio. Here are some quotes showing how teacher graduates feel about the impact of this program on their teaching:

*"Knowing the subject more makes teachable moments more common." "If you know the subject, you find the subject in everything." (From a teacher whose college major was political science.)*

*"I feel my content base is much better. Although I came to the MCE program with a fairly solid chemistry background, I feel much more knowledgeable in current chemical research and I definitely have a much better organic and inorganic chemistry base. I have also implemented a great deal of environmental chemistry issues into my classroom". (From a teacher who had a chemistry degree sometime ago.)*

*"I was not a lab person. But the labs we did in Organic and Chem. Ed really helped me to change my attitude towards lab. As a result of these courses, I started to incorporate more labs in my lesson plans. I made sure that I discussed observations that my students make at the macro levels and I also explained the reactions that were taking place at the micro level".*

Many of the teacher graduates have become teacher leaders in their schools:

*"Last year I lead a professional development for my colleagues. I demonstrated how to use the Penn Instructional model with a group of students. I also presented a short report at forum for K-12 educators at Bryn Mawr College. I discussed how MCE has enhanced my teaching."*

*"After my first summer in MCE, I was asked to give a presentation to the faculty at my school on the use of PowerPoint in the classroom. Additionally, I was asked to make a presentation last summer on the use of the PIM for lab work. This presentation was part of a teacher's summer workshop at Villanova University."*

*"I am conducting a professional workshop on safer chemical laboratory exercises later in the year sponsored by an EPA grant that I received through Rutgers University."*

Of the 120 teachers admitted into the MCE program so far, at the time of admission all of them were teaching or designated to teach chemistry. 72% of them did not have chemistry as either a major or minor of study in college. Most of their majors were in biology and science education, some in other science and engineering disciplines, and a few in social sciences or humanities. Only 15% had chemistry as a major and 13% as a minor in college. The problem is most serious among our urban school teacher-participants where nearly all of them did not have chemistry as major in college. Even among our non-urban school teacher-participants, more than half did not have chemistry as either major or minor in their college studies.

The response to these degree programs from the School Districts has been highly positive as well. Philadelphia School District has played an important role in early discussion that led to the organization of the Institute and encouraged its teachers to apply to this program. 36 schools/SD's in the greater Philadelphia area are now formal partners with the Institute in that they not only send teacher participants to the degree programs but also supervisors of the teachers to the Institute's Administrator Academy workshops aimed at providing assistance in science education in schools.

From these teacher participants, quite a few interesting observations were made. We found that even among chemistry teachers, in addition to the lack of chemistry understanding there has been a serious math phobia. Most teachers before entering the program cannot handle slightly complex mathematical operations that are needed in their classroom. It is not hard to imagine that this math phobia would be highly contagious and transferable to their students. Many teachers were great problem-solvers but their ability to apply problem solving skills to the subject they are teaching were handicapped by their limited content knowledge. And then, most teachers were unfamiliar with the communication tools now commonly available in the new electronic information age such as website creation/edition, power point presentation, etc.

It is important to recognize that for an intensive, content-based degree program to work, several ingredients are necessary: Scholarship should be provided so it is not present a financial burden to teacher participants; Classes should be conducted at times not interfering with teachers' own teaching schedule and effort; Curricular and courses should be designed specifically for teachers.

There should be financial incentives for encouraging institutions of higher education to set up or participate in such programs across the country so larger scale impact can be exerted. There should also be incentives for in-service teachers to encourage them to take on such intensive, content-knowledge based programs as means to strengthening their content preparation as well as teaching skills. States and local SD's should be encouraged to instill mechanisms or through certification process to require sufficient content preparation and renewed pedagogy training for teachers. Some States such as New York now requires teachers to obtain a master degree within 5 years of initial certification is a right direction, although 5 years may be too short to create a demanding situation for teachers to participate in a program like the MCE or MISE which takes 26 months to complete.

Finally, it is important to recognize that improving teacher content knowledge and science education pedagogy is only one important factor in the whole effort to improve students' interests and capability in science and the science literacy of the general population. Other factors such as discipline in learning and curricular requirement in pre-college education have to be considered as well. For example, increasingly, at a time that AP courses are becoming more of a norm, more and more high school students now skip the basic level course and take the AP course as the only course in that particular subject area.