AAPT Symposium on Physics Education

Under the leadership of its new Executive Officer, Toufic Hakim, the American Association of Physics Teachers (AAPT) has established a series of annual Symposia on Physics Education. The first was held at the Association's meeting in Seattle on 10 January 2007, and the principal speakers were Michael Neuschatz, Senior Research Associate of the American Institute of Physics; Kenneth Krane, Professor Emeritus of Physics at Oregon State University; and Arthur Bienenstock, President-elect of the American Physical Society and Special Assistant to the President for Federal Research Policy and Professor of Applied Physics and Materials Science & Engineering at Stanford University.

Speaking on "The Count Buildup – Rise in Undergraduate Degrees and School Enrollments in Physics," Neuschatz reported the latest trends in the number of students studying physics. Historically, physics enrollment in public U.S. high schools bottomed out at 17% between 1976 and 1986, coming down from 26% in 1948; but now the percentage of high school seniors either taking or having taken physics is up to 31%. Between 1987 and 2005 the variety of high school physics courses has increased, Neuschatz observed. The percentage of physics courses characterized as "conceptual" has increased during that period from 4% to 27%, and the percentage of course classified as "honors" or Advanced Placement has increased from 15% to 28%, thus leaving the "market share" of the "regular" physics course to shrink from 81% to 48%. Gender equity has seen an improvement as well: while only females comprised only 39% of high school physics students in 1987, this percentage was up to 47% in 2005, Neuschatz said, although there is still a disproportionate male population in Advanced Placement (AP) courses. Neuschatz offered two reasons for this increase: increased science requirements for graduation, and the need for students to present a more impressive transcript in applying for college admission. Students taking high school physics typically score higher on the SAT – and physics majors in college typically score higher on the GRE (Graduate Record Examination), he added. Neuschatz also noted a recent trend toward more physics bachelor's degrees – up to about 5000 in 2005 from a minimum of about 3600 in 1999, but still not as high as the maximum of approximately 6000 physics bachelor's degrees granted in 1969.

In speaking on "Linking Undergraduate STEM Education to the Workforce – What Physics Departments Have Done, Can Do, and Should Do," Krane noted that a generation ago, most physics departments were not concerned about what they were doing and offered more or less monolithic programs for both bachelors and doctorates. But this allowed the number of physics bachelor's degrees to decline by 25%, while the number of bachelor's degrees in *all* the sciences and computer science *increased* by 15%. Now, he went on, we need to increase enrollment and make the physics major more relevant in terms of both content and pedagogy.

Krane noted that the SPIN-UP (Strategic Programs for INnovations in Undergraduate Physics) report lists the keys to the success of institutions showing the largest increase in physics bachelor's degrees granted. Among them are career mentoring, flexible offerings (offering different tracks addressing related fields such as medicine and engineering), active SPS (Society of Physics Students) chapters, and special types of attention shown to students.

Bienenstock, addressing "Focusing on Policy and Local Action -- What the Federal and State Governments Can Do," observed that productivity must increase to keep the same standard of living as the worker/retiree ratio increases. Half the productivity increase in the last 50 years came from technology, he noted, so we must therefore have a strong science and technology workforce, a strong understanding of physics, and strong science and technology teachers. In contrast, more than 60% of high school physical science teachers have neither certification nor a major in a physical science. This is a deficiency that the "Rising Above the Gathering Storm" report (now referred to as RAGS) sought to address, as reported in our Fall 2005 issue. Yet Bienenstock lamented that instead of the 10,000 $20,000 scholarships called for in RAGS to train STEM teachers each year, Representative Vern Ehlers (R-MI) in H.R. 36 sought incentives of only $1000 per year to prepare each STEM teacher and $1500 for each year of teaching (down to $1000 a year after five years).

Actually, the Symposium was only part of a whole strand of sessions at the AAPT meeting devoted to physics education. On the meeting's opening day, 7 January 2007, Philip Sadler of Harvard University asked "Does Taking Physics Pay Off Later in Biology and Chemistry Courses?" In response to the discrepancy between the feeling of high school teachers that their students were well prepared for college physics and the feeling of college professors that they weren't, Sadler said that he sought a systematic study of which high school courses prepare students best for college science courses. In particular, he was interested in the effect of AP courses. He reported that he found that students who took AP course in high school did do better in college science courses, but he wondered whether this was because of the AP courses or because the students were smarter. Sadler found that taking an AP course with no exam led to the same success in college courses as an AP course with a score of 3. Taking a honors course was found to lead to the same college success as an AP course with a score of 2, and no science course or a "regular" course led to the same college success as an AP course with a score of 1.

Sadler also sought to test the "physics first hypothesis" by asking the following questions: 1) Does taking physics before other science courses lead to better understanding of chemistry? 2) Does taking chemistry first lead to better understanding of biology? There are few data at the high school level, Sadler said, but there is much at the college level. These data show that high school physics does not boost student performance in any college science course except college physics -- and "ditto" for high school chemistry or biology: they improve success only in college chemistry or biology, respectively. Sadler thus concluded that "physics first" appears not to make a difference in college chemistry or biology courses. What *does* matter, he observed, is the high school *mathematics* courses taken.

Robert Tai of the University of Virginia reported his research on the relationship between performance in college courses and how students spent their time in prior high school courses, and the results ran counter to expectations from the current practice of having students learn from working in small groups with a heavy emphasis on doing laboratory work. Tai reported that

1) Whether a textbook was followed in high school showed no significant effect on college grades.

2) Students spending more than an hour per day on physics in high school earned lower college grades than students spending no time at all -- and this was also true for time spent writing lab reports (Tai suggested that the time spent was an indication that the students were struggling).
3) Students spending more time in small groups in high school did poorer in college courses (Tai attributed this to too much chatter).
4) Requiring calculations in high school helped in college.
5) Spending a class period discussing results of high school demonstrations led to lower college grades, while higher college grades resulted from no discussion at all.
6) Students doing more high school laboratory experiments got lower college grades, and vice versa.

Tai suggested that, where laboratory work is concerned, quality is more important than quantity. He was also concerned about overpreparation of students for labs, though students not limited in conducting their labs also got lower college grades than those who were directed in doing them -- he concluded that a balance between guidance and autonomy is needed.

Arthur Eisenkraft of the University of Massachusetts-Boston and Director of Active Physics and Active Chemistry criticized Tai's work for being based on student-reported data without checking to confirm what actually happened with the students' teachers, also that college physics courses ignored what students had learned in high school and how they had learned it. Tai did acknowledge that the college courses were lecture-based. Another criticism of Tai's work is that correlation does not imply causality.

The second day of the meeting, 8 January 2007, saw two further sessions on various aspects of physics education. At a session on "Advanced Physics in the High School," Ingrid Novodvorsky spoke about "AP Courses," David Schuster spoke about "The IB Program," and John Truedson addressed "Dual-Enrollment Courses."

According to Novodvorsky, the AP program was established in 1955 with the participation of 60% of U.S. high schools, and 90% of US colleges and universities have a policy of granting credit for these courses, typically for exam scores greater than or equal to 3. No calculators are allowed on the multiple choice half of the AP exams, although students are allowed to approximated g by 10 m/s^2. Novodvorsky reported that in 2006 52,000 AP B exams were taken, and 35,000 AP C exams, and that this number is steadily growing. About 60% of the AP B exams resulted in a grade of 3 or better; the corresponding percentage for AP C exams was 65%.

Novodvorsky also reported 1998 CEEB data comparing scores in second college physics courses for students with different types of preparation (in contrast with Sadler's data, which reported scores in the introductory college physics course for students with different high school preparation).   The grade point average in the second college physics course was 2.67 for 4715 students taking the first college physics course in college, while for students with an AP B physics course the grade point average of 46 students with an AP score of 5 was 3.62, that for 31 students with an AP score of 4 was 3.33, and that for 41 students with an AP score of 3 was 2.89.

The grade point average in the second college physics course was 2.62 for 8056 studentstaking the first college physics course in college, while for students with an AP C (Mechanics) physics course the grade point average of 84 students with an AP score of 5 was 3.37, that for 94 students with an AP score of 4 was 2.75, and that for 90 students with an AP score of 3 was 2.81. The grade point average in the second college physics course was 2.62 for 2390 students taking the first college physics course in college, while for students with an AP C (Electricity and Magnetism) physics course the grade point average of 31 students with an AP score of 5 was 3.29, that for 33 students with an AP score of 4 was 3.01, and that for 32 students with an AP score of 3 was 2.89.

Although some colleges might question the rigor of high school AP courses, Novodvorsky said, may of these courses are very strong -- and they have the benefit of smaller enrollments. AP courses now require that 20% of instructional time be spent on laboratory work and that students keep a record of their laboratory work. To meet criticisms of the "mile wide-inch deep" characteristic of the AP B physics course by the National Research Council, the National Science Foundation has funded redesign of this course, also of the chemistry, biology, and environmental science AP courses. From the data reported by Novodvorsky, it was clear that in all cases students who entered the second college physics course from an AP course did better than those taking their first college physics course in college.

Schuster observed that the International Baccalaureate (IB) Program was founded in 1968 by a nonprofit educational foundation. Originally restricted to the high school, it now covers grades K-12 and is now found in 1700 schools, 600 of them in North America. The IB Diploma Program has requirements -- in *all* subjects -- for the last two years of high schools (24 of a maximum of 45 points are required). Physics is included in the experimental science requirement, and two years of advanced physics, algebra-based at the college level, are required. There are core topics (including measurement, mechanics, thermal physics, waves, electricity and magnetism, atomic and nuclear) and optional topics (biomedicine, history, astrophysics, relativity, optics). The IB assessment consists of external and internal exams, an essay, and a project.

Schuster reported that the scenario for one IB question involves a 40 kg girl giving a 30 kg boy a ride on the back of her bicycle and the boy wanting to jump off. Among the questions which can be asked is how much force the boy must exert on the bicycle if he jumps off in a given amount of time if he is to end up standing stationary on the street. IB grades range from 1 (weak) to 7 (excellent).

Truedson explained that Dual Enrollment means taking a course for college credit before high school graduation. He added that this may be done at a high school, on a college campus, or on-line. All 50 states recognize Dual Enrollment, but Truedson pointed out that it tends to be usedby smaller schools rather than larger ones (which tend to use AP courses). Dual Enrollment is made possible by partnerships between higher education institutions and high schools -- some higher education institutions are Kenyon College, Saint Louis University, and the University of Minnesota.

At another session on 8 January 2006 American Physical Society Education Officer Ted Hodapp spoke on "Recruiting the Next Generation of Physics Teachers." Hodapp reported that of today's physics teachers, 32% have physics degrees, 40% have teaching experience but no physics, and 28% have neither physics nor teaching experience. At the present time the number of high school students taking physics is increasing at the rate of about 1% per year and is now up to 33% (compared with 65% of high school students taking chemistry, 90% taking biology). This increase is in enrollment in both conceptual and "standard" physics courses. Like Neuschatz, Hodapp cited higher college selectivity as a motivating factor.

There are presently 21,300 physics teachers in the US, Hodapp said, and 1000 are needed each year to accommodate the 1% rate of enrollment increase, even if no physics teachers retire or leave the profession. About 8% leave the profession each year, Hodapp added, mostly due to lack of money, respect, or equipment. He lamented that the best prepared teachers are the most likely to leave and that, as the physics enrollment increases, the percentage of certified teachers decreases.

It was to increase the number of highly qualified physics teachers, improve the quality of K-8 physical science teacher education, work toward transforming physics departments to re-engage them in physics teacher preparation, and to spread best practices, amid these dismal statistics, that the PhysTEC project was founded. Much progress has been made toward achieving interactive education, Hodapp said. Now the emphasis is supporting teachers in the classroom.

PhysTEC has eight national sites (which have Teachers-in-Residence), with strong collaboration between physics and education departments. There is also a national Physics Teacher Education Coalition (PTEC) of now 62 institutions. The third national PTEC conference will be held on 4 March 2007 in Boulder (and the fourth is scheduled for 29 February-2 March 2008 in Austin).

The problem of preparing highly-qualified teachers is complex, Hodapp noted, requiring collaboration to achieve a culture shift. The Teachers-in-Residence have played a major role in achieving this. Hodapp was happy to note that PhysTEC institutions initially funded by the NSF have continued to fund it because of the favorable outcomes that have resulted (they have doubled their production of physics teachers).

Hodapp also reported that the University of Colorado invites the top 20% of their students completing introductory physics to assist in McDermott-type tutorials and also take a one-credit pedagogy course at no charge. This allows them to decide whether to pursue a teaching career without having to invest a lot of time. Hodapp added that students participating in this program also earn higher scores in subsequent physics courses.

While there is a clear need for more highly-qualified teachers, Hodapp emphasized that there is no corresponding need for more good curricula for them to teach. A lot of good curricula have already been developed, he maintained; what we need to do now is to implement it. Paul Hickman, who chairs AAPT's Committee for Teacher Preparation and presided at both 8 January sessions, added that no curriculum is "teacher-proof," but studies have shown that the results from implementing a good curriculum are pretty much independent of the teacher.