

## Strengthening High School Chemistry Education through Teacher Outreach Programs

### *A Workshop Summary to the Chemical Sciences Roundtable*

A strong chemical workforce in the United States will be essential to the ability to address many issues of societal concern in the future, including demand for renewable energy, more advanced materials, and more sophisticated pharmaceuticals. High school chemistry teachers have a critical role to play in engaging and supporting the chemical workforce of the future, but they must be sufficiently knowledgeable and skilled to produce the levels of scientific literacy that students need to succeed.

To identify key leverage points for improving high school chemistry education, the National Academies' Chemical Sciences Roundtable held a public workshop that brought together representatives from government, industry, academia, scientific societies, and foundations involved in outreach programs for high school chemistry teachers. Presentations at the workshop, which was held in August 2008, addressed the current status of high school chemistry education; provided examples of public and private outreach programs for high school chemistry teachers; and explored ways to evaluate the success of these outreach programs.

### Current State of Science and Science Education in the United States

Kathryn Sullivan, Director of the Battelle Center for Mathematics and Science Education Policy at Ohio State University, presented on the current position of the United States, compared to other countries, in terms of its investments in science education and scientific research and development. Within the United States, science and engineering job opportunities have outpaced job growth in other sectors of the economy for decades, and funding for science and engineering continues to grow. But, based on data from Science and Engineering Indicators 2008, Sullivan showed that two key indicators of investment in the sciences—research and development funding levels and the number of college and doctoral degrees awarded—have become more internationally distributed in recent years, despite continued growth in United States funding levels.



Sullivan also pointed to an increased need for highly qualified high school chemistry teachers in the United States. Studies show that students' proficiency in mathematics has generally increased in recent decades, but proficiency in science has been stable or slipped slightly. In addition, the percentage of U.S. students taking chemistry in high school increased from 44 percent in 1990 to 55 percent in 2000. These circumstances—stable/declining proficiency combined with increasing enrollment—make it particularly important that high school chemistry teachers be highly qualified and well-prepared. Unfortunately, opportunities for teachers to improve are not always adequately supported: despite the evidence that 40 to 50 hours of subject matter professional development is needed to have an effect on teacher practice, competency, and content knowledge, teachers are only getting an average of 32 hours.

## Status of High School Chemistry Education

Other speakers at the workshop discussed the current state of high school chemistry education and the outreach activities that are needed to better support chemistry teachers. One speaker presented research showing that chemistry students perform better in



college when they study a high level of mathematics, are exposed to particular subjects like stoichiometry, and engage in frequent peer interactions in high school chemistry

classes. Conversely, time spent on community and student projects, instructional technologies, and labs can be negatively associated with college chemistry grades. Speakers indicated that laboratories in high school chemistry in practice, unfortunately, tend to be disconnected from coursework, focus on procedures rather than clear learning outcomes, and provide few opportunities for discussion or reflection. A major challenge for teacher outreach programs is to help teachers to illuminate the linkages between chemistry and everyday experiences, especially through hands-on activities.

High school chemistry teachers enter the profession one of three ways: directly out of college, after several years in industry, or via a complete career change. Whatever their pathway, all of these teachers need professional development. Most high school chemistry teachers have taken college courses above the level they are assigned to teach, but they report needing help in using technology in science instruction, teaching classes with special needs students, and using inquiry-oriented teaching methods. Some science teachers must teach outside of their area of expertise, and new requirements that high school students take more advanced science courses have increased the need for well-prepared chemistry teachers. Despite these needs, finding the time and financial support for professional development is a major challenge for teachers. This is an issue that teacher outreach activities may need to address.

## Current Initiatives

Workshop speakers discussed examples of publicly-funded government and university programs, along with programs privately funded through for-profit and non-profit institutions. Examples of current

chemistry education teacher outreach programs are shown in Box 1. The programs have much in common. Many focus on making inquiry-based learning more prevalent and effective. They also have in common some primary challenges: attracting teachers to the programs, and fostering teacher improvement on a large scale.

### *Government-sponsored Programs*

Government sponsored programs include those operated by the National Institutes of Health, the National Science Foundation, and the Department of Energy Office of Science. Many of these programs are centered on increasing the content knowledge of participants and providing laboratory experiences that provide background for implementing inquiry-based learning. In particular, the Department of Energy uses its national laboratories as a venue for chemistry teachers to gain hands-on research experience. Another key feature of many government-sponsored programs is developing collaborations and partnerships with school districts, which can be crucial to a program's effectiveness. These programs often try to achieve a large scale impact through the use of "teacher leaders," who are program participants that go back to their districts and share what they have learned with their colleagues.

### *University-based Initiatives*

The workshop also presented examples of particularly successful programs that had been led by universities. These programs include the ChemEd conferences, held every two years at a host university, and programs managed by the University of Pennsylvania, University of California – Irvine, and Miami University. Like the government programs, these programs are generally focused on increasing content knowledge and providing laboratory experiences. Workshop participants discussed strategies for encouraging teacher participation in these programs: one effective method that was identified was to offer stipends or course credit. In terms of program content, a common theme of the discussions was that scientific explanation has more impact on learners (in this case, high school science teachers) when it is combined with related hands-on experiences.

### *Privately-sponsored Programs*

For-profit and non-profit programs cover a wide range of activities, including workshops, scholarships and development of educational materials. They also have a broad group of target audiences, from K-12

educators to undergraduates, graduate students, and the general public. Bayer Corporation, ASSET, the American Chemical Society, Hach Scientific Society, and the Howard Hughes Medical Institute each discussed programs they manage and support. During these discussions, one theme that emerged is the idea that developing novel and effective educational materials can help programs overcome the challenge of reaching large numbers of teachers.

## Evaluating Success and Looking to the Future

The workshop was structured to emphasize program evaluation as a key factor in determining the effectiveness of different approaches. Many workshop participants agreed that evaluation was very challenging, but also very necessary to determine the most effective outreach methods. Some programs evaluate content knowledge before and after the

outreach programs to determine effectiveness. Others ask teachers who go through a program to compare it to other outreach activities and evaluate the extent to which the different programs have influenced their teaching. The most rigorous evaluations assessed improvements in attitudes and understanding of science among students of teachers who participated in a program.

One major challenge that participants identified was how to ensure that once good practices are identified—both for teaching high school chemistry and for conducting outreach programs geared toward teachers—that these practices could be widely disseminated. Education is largely a local enterprise: even when a good practice is identified, it is difficult to convince each of the approximately 16,000 school districts in America to adopt it.

The workshop ended with a panel to consider what future actions could be useful in improving teacher outreach programs. The panel was comprised

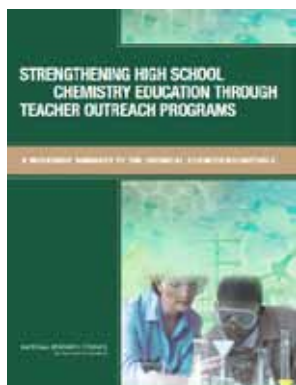
**Box 1: Examples of Outreach Programs**

Name of Program	URL
<b>Program for In-Service Teachers</b>	
National Institutes of Health: Science Education Partnership Award	<a href="http://www.ncrr.nih.gov/science_education_partnership_awards/">http://www.ncrr.nih.gov/science_education_partnership_awards/</a>
National Science Foundation: Math and Science Partnership	<a href="http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5756">http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5756</a>
Department of Energy: Academic Creating Teacher Scientists	<a href="http://education.llnl.gov/doeacts/">http://education.llnl.gov/doeacts/</a>
ChemEd Conferences (2009 Conference at Radford University)	<a href="http://www.radford.edu/~chemed2009/">http://www.radford.edu/~chemed2009/</a>
University of Pennsylvania Science Teacher Institute	<a href="http://www.sas.upenn.edu/PennSTI/">http://www.sas.upenn.edu/PennSTI/</a>
University of California, Irvine	<a href="http://chem.ps.uci.edu/~mtaagepe/SciEd/Programs.html#1">http://chem.ps.uci.edu/~mtaagepe/SciEd/Programs.html#1</a>
Miami University: Terrific Science: Empowering Teachers Through Innovation	<a href="http://www.terrificscience.org/">http://www.terrificscience.org/</a>
<b>Other Outreach Resources</b>	
NSF: Robert Noyce Teacher Scholarship	<a href="http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5733">http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5733</a>
NSF: Discovery Research K-12	<a href="http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=500047">http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=500047</a>
NSF: Graduate Teaching Fellows in K-12 Education	<a href="http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5472">http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5472</a>
Bayer Corporation: Making Science Make Sense	<a href="http://www.bayerus.com/msms/MSMS_Home.aspx">http://www.bayerus.com/msms/MSMS_Home.aspx</a>
ASSET: Achieving Student Success Through Excellence in Teaching	<a href="http://www.assetinc.org/">http://www.assetinc.org/</a>
American Chemical Society Summer Workshops	<a href="http://www.divched.org/">http://www.divched.org/</a>
Hach Scientific Foundation	<a href="http://www.hachscientificfoundation.org/home.shtml">http://www.hachscientificfoundation.org/home.shtml</a>
Howard Hughes Medical Institute	<a href="http://www.hhmi.org/grants/">http://www.hhmi.org/grants/</a>

of representatives from the American Chemical Society, National Science Teachers Association, National Science Foundation, and two university level chemistry educators. The panel discussed possible improvements in coordination and program evaluation, and discussed the merits of focusing on the early stages of education as a part of a comprehensive effort to improve U.S. science education overall.

## Chemical Sciences Roundtable

The Chemical Sciences Roundtable (CSR) is a unique science-oriented, apolitical forum of leaders of the chemical enterprise that serves as a vehicle for education, exchange of information and discussion of issues and trends that affect the chemical sciences. The CSR accomplishes this through meetings of its members, and through organizing public workshops on highly relevant and important topics—for which published summaries are made broadly available. The CSR's charter enables government representatives to serve as full members, but consequently precludes it from providing advice and recommendations.



**Chemical Sciences Roundtable:** **Charles P. Casey** (*Co-chair*), University of Wisconsin; **Sharon Haynie** (*Co-chair*), E. I. du Pont de Nemours & Company; **Patricia A. Baisden**, Lawrence Livermore National Laboratory; **Mark A. Barteau**, University of Delaware; **Michael R. Berman**, Air Force Office of Scientific Research; **Apurba Bhattacharya**, Texas A&M; **Louis Brus**, Columbia University; **Paul F. Bryan**, Biofuels Technology Chevron Technology Ventures LLC; **Mark Cardillo\***, Camille and Henry Dreyfus Foundation; **William F. Carroll Jr.\***, Occidental Chemical Corporation; **Marvin H. Caruthers**, University of Colorado; **John C. Chen**, Lehigh University; **Luis Echegoyen**, National Science Foundation; **Barbara J. Finlayson-Pitts**, University of California; **Gary J. Foley**, U.S. Environmental Protection Agency; **Teresa Fryberger**, NASA Earth Sciences Division; **Alex Harris\***, Brookhaven National Laboratory; **Luis E. Martinez**, The Scripps Research Institute; **John J. McGrath**, National Science Foundation; **Paul F. McKenzie**, Centocor R&D; **Douglas Ray**, Pacific Northwest National Laboratory; **Michael E. Rogers**, National Institute of Health; **Eric Roling**, U.S. Department of Energy; **James M. Solyst**, ENVIRON International Corporation; **Levi Thompson**, University of Michigan; **Steve Olsen**, Rapporteur; **Sheena Siddiqui**, Research Assistant; **Andrew Crowther**, Postdoctoral Research Associate; **Tina Masciangioli**, Study Director, National Research Council

\* These members of the Chemical Sciences Roundtable oversaw the planning of the Workshop on Strengthening High School Chemistry Education through Teacher Outreach Programs, but were not involved in the writing of the workshop summary or brief.

For more information, contact the Board on Chemical Sciences and Technology at (202)334-2156 or visit <http://www.dels.nas.edu/bcst/>. Copies of *Strengthening High School Chemistry Education through Teacher Outreach Programs: A Workshop Summary to the Chemical Sciences Roundtable* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; [www.nap.edu](http://www.nap.edu).

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