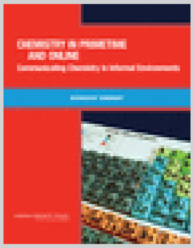


Chemistry in Primetime and Online: Communicating Chemistry in Informal Environments

ISBN
978-0-309-18770-1

102 pages
8 1/2 x 11
PAPERBACK (2011)

Tina Masciangioli, Rapporteur; Chemical Sciences Roundtable; National Research Council

CHEMISTRY IN PRIMETIME AND ONLINE
Communicating Chemistry in Informal Environments

WORKSHOP SUMMARY

Tina Masciangioli, *Rapporteur*

Chemical Sciences Roundtable

Board on Chemical Sciences and Technology

Division on Earth and Life Studies

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

THE NATIONAL ACADEMIES PRESS **500 Fifth Street, N.W.** **Washington, DC 20001**

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This material is based upon work supported by the U.S. Department of Energy under Grant DE-FG02-07ER15872, the National Institutes of Health under Grant N01-OD-4-2139 (Task Order 25), and the National Science Foundation under Grant CHE-0621582.

International Standard Book Number-13: 978-0-309-18770-1
International Standard Book Number-10: 0-309-18770-2

Additional copies of this report are available from the National Academies Press, 500 Fifth Street, N.W., Lockbox 285, Washington, DC 20055; (800) 624-6242 or (202) 334-3313 (in the Washington metropolitan area); Internet, http://www.nap.edu.

Printed in the United States of America

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Ralph J. Cicerone is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Charles M. Vest is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Ralph J. Cicerone and Dr. Charles M. Vest are chair and vice chair, respectively, of the National Research Council.

www.national-academies.org

CHEMICAL SCIENCES ROUNDTABLE

CHAIR

MARK A. BARTEAU, University of Delaware, Newark, Delaware
WILLIAM F. CARROLL JR.,* Occidental Chemical Corporation, Dallas, Texas

MEMBERS

MICHAEL R. BERMAN, Air Force Office of Scientific Research, Arlington, Virginia
APURBA BHATTACHARYA, Texas A&M, Kingsville, Texas
PAUL F. BRYAN, Biomass Program, U.S. Department of Energy, Washington, D.C.
MARK CARDILLO,* Camille and Henry Dreyfus Foundation, New York
ROBERT J. CELOTTA, National Institute of Standards and Technology, Gaithersburg, Maryland
JOHN C. CHEN, Lehigh University, Bethlehem, Pennsylvania
JENNIFER SINCLAIR CURTIS, University of Florida, Gainesville
TERESA FRYBERGER, NASA Earth Sciences Division, Washington, D.C.
JOHN W. KOZARICH, ActivX Biosciences Inc., La Jolla, California
LUIS E. MARTINEZ, Private Consultant, Jupiter, Florida
JOHN J. MCGRATH, National Science Foundation, Arlington, Virginia
KENNETH G. MOLOY, DuPont Company Experimental Station, Wilmington, Delaware
ROBERT PEOPLES, American Chemical Society, Washington, D.C.
MATTHEW PLATZ, National Science Foundation, Arlington, Virginia
DOUGLAS RAY, Pacific Northwest National Laboratory, Richland, Washington
MICHAEL E. ROGERS,* National Institutes of Health, Bethesda, Maryland
ERIC ROHLFING, U.S. Department of Energy, Germantown, Maryland
JAMES M. SOLYST,* ENVIRON International Corporation, Arlington, Virginia
PATRICIA A. THIEL, Iowa State University, Ames
LEVI THOMPSON, University of Michigan, Ann Arbor
RICHARD P. VAN DUYNE, Northwestern University, Evanston, Illinois

NATIONAL RESEARCH COUNCIL STAFF

DOROTHY ZOLANDZ, Director
AMANDA CLINE, Administrative Assistant
KATHRYN HUGHES, Program Officer
TINA M. MASCIANGIOLI, Responsible Staff Officer
ANGELA OLSON, Christine Mirzayan S&T Policy Fellow (January-April 2011)
SHEENA SIDDIQUI, Research Associate
RACHEL YANCEY, Program Assistant

---

* These members of the Chemical Sciences Roundtable oversaw the planning of the Workshop on Chemistry in Primetime and Online: Communicating Chemistry in Informal Environments, but were not involved in the writing of this workshop summary.

Preface

The Chemical Sciences Roundtable (CSR) was established in 1997 by the National Research Council. It provides a science-oriented apolitical forum for leaders in the chemical sciences to discuss chemistry-related issues affecting government, industry, and universities. Organized by the National Research Council's Board on Chemical Sciences and Technology, the CSR aims to strengthen the chemical sciences by fostering communication among the people and organizations—spanning industry, government, universities, and professional associations—involved with the chemical enterprise. One way it does this is by organizing workshops that address issues in chemical science and technology that require national or more widespread attention.

In May 2010, the CSR organized a workshop on the topic "Chemistry in Primetime and Online: Communicating Chemistry in Informal Environments." The one-and-a-half-day workshop was held to

- Examine science content, especially chemistry, on television, on the Internet, in museums, and in other informal educational settings,
- Explore how the public obtains scientific information, and
- Discuss methods chemists can use to improve and expand their efforts to reach a general, nontechnical audience.

Specific consideration was given to the rapid changes taking place in mass media communication and the opportunities that interactive web technologies may provide scientists in developing and distributing materials for informal education. Means of measuring recognition and retention of the information presented in various media formats and settings was also discussed.

Workshop participants included chemical practitioners (e.g., graduate students or postdocs, professors, administrators); informal learning experts; public and private funding organizations; science writers, bloggers, publishers, and university communications officers; and television and web producers.

This document summarizes the presentations and discussions that took place at the workshop. In accordance with the policies of the CSR, the workshop did not attempt to establish any conclusions or recommendations about needs and future directions, focusing instead on issues identified by the speakers and workshop participants. In addition, the organizing committee's role was limited to planning the workshop. The workshop summary has been prepared by the workshop rapporteur Tina Masciangioli as a factual summary of what occurred at the workshop.

IMPORTANT NOTE ABOUT INTERNET WEBSITES

The Internet information provided in this Summary was correct, to the best of our knowledge, at the time of publication. It is important to remember, however, the dynamic nature of the Internet. Information on websites can be transient, and is not always validated or verifiable. Resources that are free and publicly available one day may require a fee or restrict access the next, and the location of items may change as menus and homepages are reorganized.

Acknowledgment of Reviewers

This workshop summary has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published summary as sound as possible and to ensure that the summary meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this workshop summary:

Jo Ann Caplin, Science TV Workshop, Wynnewood, Pennsylvania
Jennifer S. Curtis, University of Florida, Gainesville
Al Hazari, University of Tennessee, Knoxville
Terri M. Taylor, American Chemical Society, Washington, DC
David R. Walt, Tufts University, Medford, Massachusetts

Although the reviewers listed above have provided many constructive comments and suggestions, they did not see the final draft of the workshop summary before its release. The review of this summary was overseen by **Jeffrey I. Steinfeld**, Massachusetts Institute of Technology, Cambridge. Appointed by the National Research Council, he was responsible for making certain that an independent examination of this summary was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this summary rests entirely with the author and the institution.

Contents

APPENDIXES

Acronyms

AAAS American Association for the Advancement of Science
ACC American Chemistry Council
ACS American Chemical Society
AIChE American Institute of Chemical Engineers
AP Advanced Placement
ASTC Association of Science and Technology Centers

CAISE Center for Advancement of Informal Science Education
CHF Chemical Heritage Foundation
CRPA Communicating Research to Public Audiences
CSI Crime Science Investigation

EA Electronic Arts

IGERT Integrative Graduate Education and Research
ISE Informal Science Education
IYC 2011 International Year of Chemistry 2011

NCW National Chemistry Week
NIH National Institutes of Health
NISE Nanoscale Informal Science Education
NRC National Research Council
NSDL National Science Digital Library
NSF National Science Foundation

PBS Public Broadcasting Service
PROS Parallel Remote Online System

SMILE Science and Math Informal Learning Educators
STEM science, technology, engineering, or mathematics

1

Overview

Globalization and emerging economies around the world offer challenges to the economic position and quality of life that Americans enjoy, and experts worry that a lack of scientific and technical understanding in the United States could hamper its ability to lead in the future.[1] Formal education and preparation of students from K-12 to the graduate school level and beyond is vital for developing science literacy. However, informal learning opportunities such as family TV viewing or visiting a museum or an Internet website can engage and educate the population more broadly.[2] In fact, most Americans learn about science outside of school[3] and primarily obtain science and technology (S&T) information from television and the Internet.[4]

Yet in these informal settings, such as watching television, little primary chemistry content is found.[5] Chemists often voice frustration about their inability to effectively communicate their ideas to the general public outside the formal classroom or research laboratory setting. New modes of communication on the Internet such as video sharing (e.g., YouTube), social networking (e.g., Facebook), and microblogging (e.g., Twitter) present new and possibly improved opportunities for chemists to communicate with the public, but it is not clear whom these media formats reach or how effectively they present specific messages. The chemical sciences and technology community could increase its impact on improving general chemical literacy by evaluating current approaches to informal education and learning how best to navigate both new and old media.

ABOUT THIS DOCUMENT

The National Academies' Chemical Sciences Roundtable (CSR) held a workshop on May 26-27, 2010, to examine the challenges and opportunities to presenting chemistry content on television, the Internet, in museums, and in other informal educational settings. The workshop "Chemistry in Primetime and Online: Communicating Chemistry in Informal Environments" explored how the public obtains scientific information informally and discussed methods that chemists can use to improve and expand efforts to reach a general, nontechnical audience. Workshop participants included chemical practitioners (e.g., graduate students, postdocs, professors, administrators); experts on informal learning; public and private funding organizations; science writers, bloggers, publishers, and university communications officers; and television and Internet content producers. This workshop featured invited presentations, discussions, and a poster session that highlighted key informal education activities in the chemical sciences.

This document summarizes the presentations and discussions that took place at the workshop. Where possible, background references have been provided to support statements made or data described. In addition, the Internet information

[1]National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. 2007. *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. Washington, DC: National Academies Press.

[2]Philip Bell, Bruce Lewenstein, Andrew W. Shouse, and Michael A. Feder, Editors, Committee on Learning Science in Informal Environments, National Research Council. 2009. *Learning Science in Informal Environments*. Washington, DC: National Academies Press. Available online at *www.nap.edu/catalog.php?record_id=12190*.

[3]J.H. Falk, and L.D. Dierking, 2010. The 95 percent solution (School is not where most Americans learn most of their science) *American Scientist* 98: 486-493.

[4]Science and Engineering Indicators. 2010. *http://www.nsf.gov/statistics/seind10/?org=DRL*. Pew General Public Survey. 2009. *http://people-press.org/report/?pageid=1552*.

[5]B. Halford. 2008. Stephen Lyons: A television producer's take on what makes good chemistry for the small screen. *Chemical and Engineering News* 86(39)41.

provided was correct, to the best of our knowledge, at the time of publication. It is important to remember, however, that information on websites can be transient and is not always validated or verifiable. The reader is urged to follow up with individual guest speakers and their institutions for further clarification of statements made during the workshop or to obtain additional reference materials.

Important Note about Open Discussions: Each chapter in this document ends with a summary of discussion topics introduced by speakers and participants in the immediate session (chapter), as well as all preceding workshop sessions.

WORKSHOP OVERVIEW

The workshop began with an introduction to informal learning and how it relates to chemistry, including how the public obtains scientific information and effective methods used to communicate science more broadly. There were then several panels of speakers focused around media formats and venues where chemistry content is communicated, which form the structure of this document: print, hands-on outreach, museums, video & radio, gaming, and libraries. The workshop ended with a wrap-up panel consisting of four participants, who attended both days of the event and agreed in advance to comment on important messages they heard during the workshop.

Key issues raised during the workshop include the following:

- The deficiency in public understanding of chemistry;
- Chemists' ability or inability to communicate effectively;
- The need for different approaches to communication for different goals (i.e., promotional, marketing, advocacy, educational);
- The importance of highlighting the human side of chemistry;
- The difficulty in assessing the effectiveness of various communication venues;
- The need for studying and evaluating different approaches to communicating chemistry;
- The importance of formal education in setting the stage for informal interactions with chemistry and chemists;
- The role that technology plays in communicating chemistry in informal environments;
- Losing the "chemistry" when communicating about chemistry applications;
- The need for chemists to connect more with professional writers, artists, or videographers, who know how to communicate with and interest general audiences.

Informal Chemistry

In this session, an introduction to informal education was provided by **Kirsten Ellenbogen**, Science Museum of Minnesota and member of the National Research Council Committee on Learning Science in Informal Environments. The connection between chemistry and informal education was presented by **David Ucko** of the National Science Foundation. **Stephen Lyons,** with Moreno-Lyons Productions, discussed the role of documentary films in communicating science and how chemistry is one of the few fields that have been neglected by informal media sources.

Chemistry in Print

This session focused on the ways chemistry is presented informally through literature, print media, and blogs. **John Emsley** from the University of Cambridge discussed steps to becoming a science writer and explained how the struggles of a chemistry writer may differ from other types of writers. **Ivan Amato** of the Pew Charitable Trusts, a former writer and editor at *Chemical and Engineering News*, pointed out how chemistry is ignored by media, but also discussed the opportunities that exist to highlight chemistry, especially through chemical imagery. **Joy Moore** from Seed Media Group provided insights into how her company has been using print media and science blogs to promote a better understanding of chemistry.

Local Outreach Efforts

This session included personal experiences from local outreach experts and how they introduce informal science to their communities. **Jeanette Brown** of the New Jersey American Chemical Society (ACS) local section shared her experience as a chemistry ambassador, conducting hands-on activities at festivals and other events, as well as creating educational resources about African-American chemists. **Ruth Woodall** of the Nashville ACS local section also discussed being a chemistry ambassador and how she introduces chemistry to public audiences, especially young people. **Catherine Conrad** from St. Mary's University presented a very different approach to local outreach called citizen science, where nonscientists help collect real scientific data. Conrad explained how she became involved in citizen science and how it has benefited her research as well as her local community.

Chemistry in Museums

In this session, speakers described various approaches to informal learning of chemistry in museums. **Sapna Batish** of the Koshland Science Museum showed current exhibits featured at the museum and how chemistry content is incorporated into the exhibits. **Susanne Rehn** of the Deutsche

Museum described the chemistry exhibitions that have existed at the museum for many years and shared the details of, and rationale for, the extensive renovations under way to update and improve the exhibits. **Shelley Geehr** with the Chemical Heritage Foundation (CHF) discussed the recently created CHF museum, including museum exhibits, special events, and other CHF resources available to the public. Lastly, **Peter Yancone** with the Maryland Science Center presented the chemistry-related activities at the museum.

Chemistry in Video and on the Radio

This panel focused on the role of video and radio in informal science education. **Martyn Poliakoff** from the University of Nottingham described how he and his team created the very successful Periodic Table of Videos on the Internet, which features short videos about each of the elements of the Periodic Table. **Jorge Salazar** of EarthSky Communications described his organization's efforts to provide a commercial-free way for scientists to communicate their research to the public through audio and video on the radio and over the Internet. **Mark Griep** from the University of Nebraska-Lincoln discussed his analysis of chemistry content in films and explained how popular movies can play a major role as an informal educational tool for understanding chemistry.

Tools and Techniques

In this session, speakers shared insights on new tools and techniques for communicating chemistry in informal environments. **Robert Hone** of Red Hill Studios shared his insights on creating educational video games. He explained different gaming design strategies and the strengths and weaknesses of using games as tools for informal education. **Deborah Illman** from the University of Washington discussed her ongoing efforts to provide communications training for scientists and her recent focus on working with chemists. **Andrea Twiss-Brooks** from the University of Chicago explained the important and changing role that libraries and librarians play as a source of informal science. She also discussed how the ACS Committee on Community Activities is trying to better collect data and evaluate the effectiveness of its outreach efforts.

Workshop Wrap-up Session

This session included four panelists with diverse perspectives who attended the entire workshop. They were asked to provide impromptu comments on what they heard during the workshop talks and discussions. **David Ucko** of the National Science Foundation provided a perspective from a government funding agency. **Nancy Blount** with the American Chemical Society presented views from the main professional organization for chemists. **Joy Moore** with Seed Media Group commented from the perspective of new media and communications. CSR co-chair **Mark Barteau** from the University of Delaware provided an academic perspective.

2

Introduction to Informal Learning

"Most people, most of the time, learn most of what they know outside the classroom."

—George Tressel (quoted by David Ucko)

When most people think of learning about science, a classroom or laboratory setting comes to mind, students being taught by teachers according to a set curriculum and following a textbook. They picture a formal educational environment. However, children and adults actually learn about science continuously, through a variety of ways and settings such as visiting museums, watching television, or exploring outdoors, by what is called informal education. In this opening session of the workshop, three speakers offered introductory remarks about informal education and effective communication of scientific content. **Kirsten Ellenbogen** from the Science Museum of Minnesota provided an overview of informal education, **David Ucko** of the National Science Foundation talked about the connection between chemistry and informal education, and filmmaker **Stephen Lyons** discussed the changing role of video and films in communicating chemistry. In addition, the speakers specifically addressed the challenges and opportunities for communicating chemistry content to public audiences in informal learning environments.

SURROUNDED BY SCIENCE

Kirsten Ellenbogen started the morning off by immersing the group in the volume from the National Research Council (NRC) *Learning Science in Informal Environments* (*LSIE*)[1] and its companion volume *Surrounded by Science* (Figure 2-1).[2] Ellenbogen discussed the main conclusions and research underlying the reports, the ways in which the field of informal education is starting to use the reports, and the relevance of informal education to chemistry.

Lifelong, Life-Wide, Life-Deep Learning

Ellenbogen explained that one premise of the report is that learning is lifelong, life wide, and life deep, encompassing formal and informal education.[3] Figure 2-2 illustrates this point, showing the significant percentage of time in a person's life that is spent in informal versus formal education. The blue area, referred to as the "sea of blue" throughout this workshop, represents the time spent in informal educational environments; the black area represents the time spent in formal education.

Ellenbogen said that one exciting conclusion of the *LSIE* report was that many opportunities exist to fill the unused educational time and provide an interconnected network of informal learning environments. "There is abundant evidence of learning in everyday environments. . . . That includes settings like museums, experiences like watching a television show."

Strands of Learning

Ellenbogen explained how the *LSIE* report emphasizes six strands of learning (Box 2-1). She emphasized that the concept of calling the aspects of science learning "strands" is not unique to this report; it has been used in some other NRC reports. The strand concept reinforces the idea that

[1] Philip Bell, Bruce Lewenstein, Andrew W. Shouse, and Michael A. Feder, Editors, Committee on Learning Science in Informal Environments, National Research Council. 2009. *Learning Science in Informal Environments*. Washington, DC: National Academies Press.

[2] Marilyn Fenichel and Heidi A. Schweingruber, National Research Council. 2010. *Surrounded by Science*. Washington, DC: National Academies Press.

[3] The LIFE Center (The Learning in Informal and Formal Environments Center), University of Washington, Stanford University, and SRI International. 2007. Learning in and out of school in diverse environments: Life-long, life-wide, life-deep. Available online at *http://depts.washington.edu/centerme/LEARNING%20LIFE%20REPORT.pdf.*

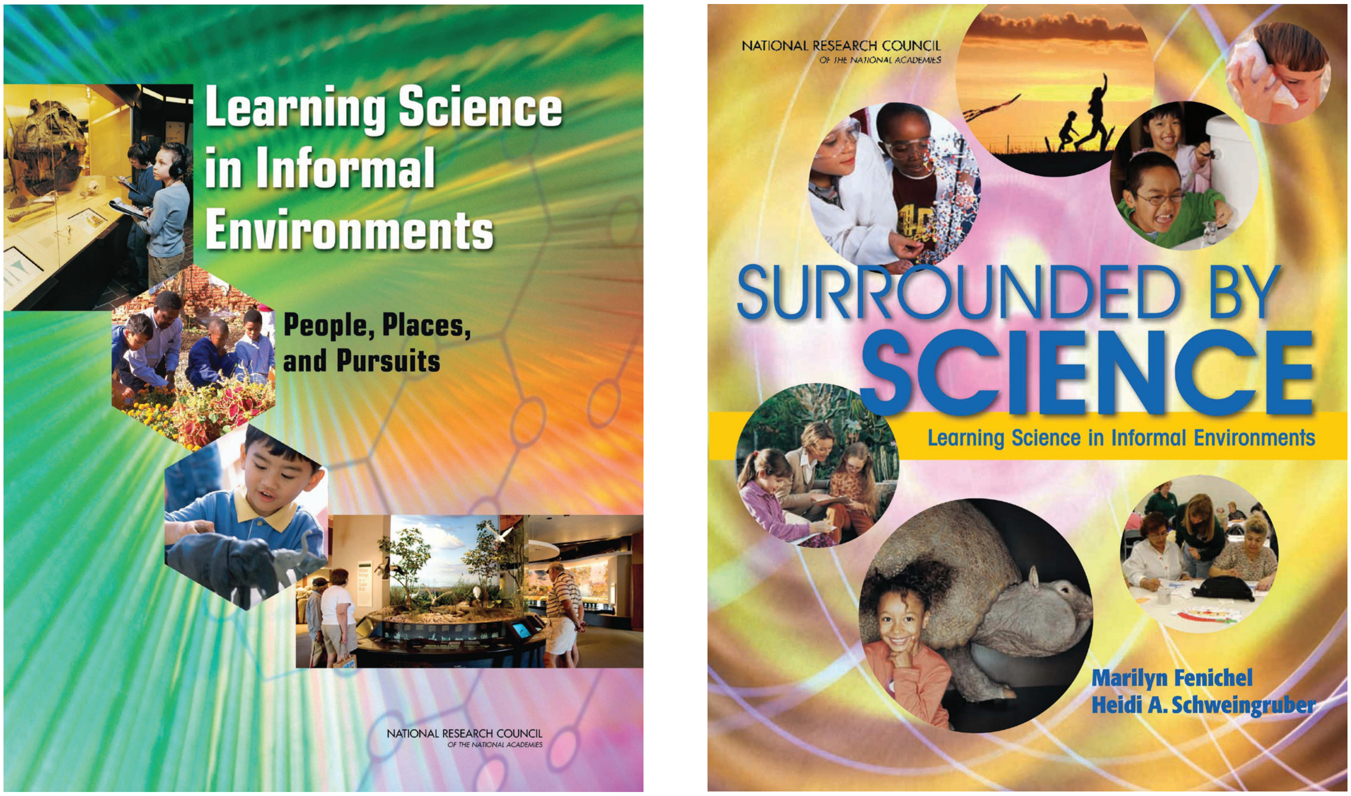


FIGURE 2-1 Cover images of recent National Research Council reports on informal education.
SOURCE: Philip Bell, Bruce Lewenstein, Andrew W. Shouse, and Michael A. Feder, Editors, Committee on Learning Science in Informal Environments, National Research Council. 2009. *Learning Science in Informal Environments*. Washington, DC: National Academies Press; Marilyn Fenichel and Heidi A. Schweingruber, National Research Council. 2010. *Surrounded by Science*. Washington, DC: National Academies Press.

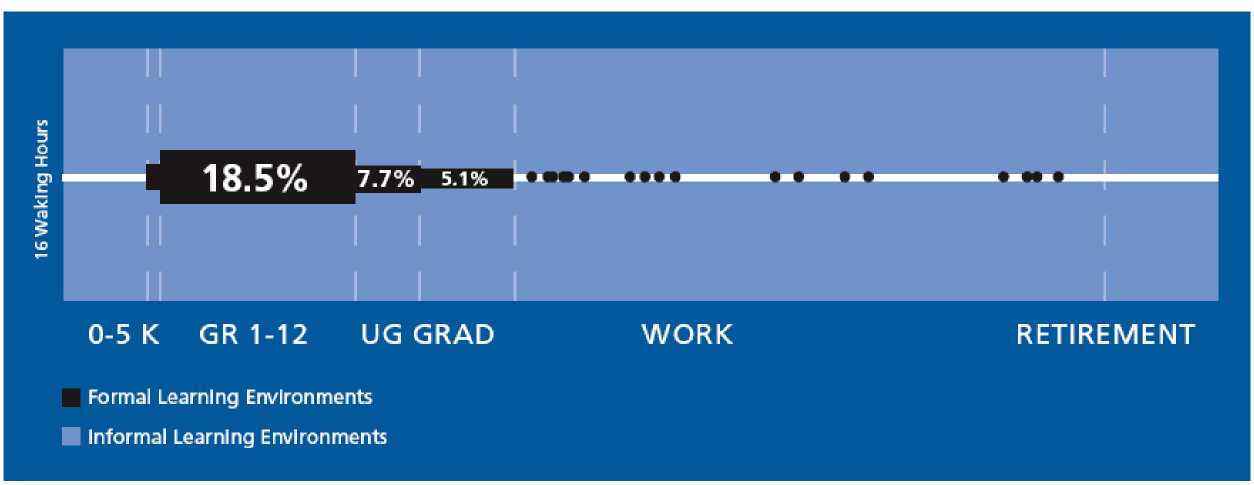


FIGURE 2-2 Map of human learning, which shows that people spend the majority of their time from infancy to adulthood in informal learning settings.
SOURCE: The LIFE Center (The Learning in Informal and Formal Environments Center), University of Washington, Stanford University, and SRI International. 2007. Learning in and out of school in diverse environments: Life-long, life-wide, life-deep. Available online at *depts.washington.edu/centerme/LEARNING%20LIFE%20REPORT.pdf*.

BOX 2-1 Strands of Science Learning

Learners in Informal Environments

Strand 1: Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world.

Strand 2: Come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science.

Strand 3: Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world.

Strand 4: Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena.

Strand 5: Participate in scientific activities and learning practices with others, using scientific language and tools.

Strand 6: Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science.

these aspects of learning are not individual elements that stand alone in informal education experiences. "These are literally strands or threads that are interwoven throughout many of the experiences. . . . In many instances, it is almost impossible to separate out one part of the experience from another part of the experience, to identify which moment in the learning experience relates to which aspect of the learning strand." Learning is not just about content; it is also about the processes of science.

Another point made by Ellenbogen is that strands 2 through 5 are also in the volume *Taking Science to School*, which focuses on K-8 learning in school environments. "This was an important part of the *LSIE* report that was able to show good evidence that there is a strong overlap between what happens in our formal learning environments and what happens in informal learning experiences," she said.

The difference between the two reports is the inclusion of strand 1, excitement and motivation, and strand 6, identity development, as part of informal education. "It is not to say that [strands 1 and 6] don't happen in school environments, but they are such a critical and strong part of what happens in informal learning experiences, we pulled them out into their own strands."

Ellenbogen showed many examples of informal learning from her museum. She emphasized that she only provided a few examples, and there are thousands of research publications and evaluation reports referenced in the *LSIE* volume. At the same time, she noted that one of the interesting things to come out of the study is there is still a great deal unknown, despite the rich body of research and evaluation in informal science education, She said there is a lot to be learned about effectiveness of different media formats and how they lead to good decision making in people's everyday life.

One issue in particular she mentioned is a lack of longitudinal studies on informal learning—"of following a learner through school experiences and home experiences and museum experiences and looking at those over time, and the connections between conversations in the home and how they related to conversations back in the museum." It is still difficult to obtain the larger longitudinal view needed to connect an informal educational experience with the impact it may have on how an individual uses science or pursues a career in science, technology, engineering, or mathematics (STEM).

In addition, she said, "we know very little about the cumulative effects. People talk about informal learning experiences being these very particular moments in time [to which] we as complex humans can attach various experiences throughout our life, drawing back many times on information or experiences from decades ago in a very meaningful way. David Anderson at the University of British Columbia in Vancouver has some great examples of this and interviews that he has done with people about their World's Fair experience, decades and decades after they went to the World's Fair."

Ellenbogen concluded by mentioning that there are a number of commissioned papers available, in addition to the *LSIE* and *Surrounded by Science* reports, from the National Academies Board on Science Education.[4]

[4]For more information, see *www7.nationalacademies.org/bose/BOSE_Resources.html* (accessed December 27, 2010).

Questions & Answers

Reflective Experiences

A workshop participant asked if there is a way to design an "ah-ha" moment into the learning environment for children or adults: "For many of us as professional scientists, this is the moment that we treasure, when something finally clicks and you integrate a lot of observations."

Ellenbogen said that such moments are connected to the reflective needs of the learning experience. She said there is not much evidence in the literature of reflective experiences being integrated consistently into the design of learning environments. However, museums are now incorporating them into exhibits.

For example, the Science Museum of Minnesota is developing "tinkering spaces" or engineering labs "that give learners real questions to grapple with, issues that we don't exactly have clear answers on." Ellenbogen said the exhibit is set up as a reflective experience that has focused rings of participation. "On the outer ring it asks some very basic questions and engages you in some exploration of phenomena, but as you move in and go into an area that has to be facilitated by staff, there are actual fabrication tools that allow you to try to design and build something that responds to the question or issue at hand."

Ellenbogen stated that different media sources are also trying to introduce this type of experience, such as in television or radio segments where they ask questions designed to cause a reflective conversation among the social group who may be watching the video or listening to that radio show. "It is something that is really underutilized in an informal learning experience."

Science Identity

Bill Carroll asked how children come to identify with being a scientist. He mentioned how some kids seem to look at science and say, "I just don't think I can do that."

Ellenbogen mentioned the *LSIE* report has evidence and commentary on this in a variety of chapters. "If you want to look at the lifetime of the learner, it starts in the conversations and research on adult-child interactions in homes, in family units, and the notion that very early on, conversations position science as something we do or something that we like."

There have been some insights from interviews with well-known scientists about early formative experiences. For example, many scientists recall being collectors in childhood. However, collecting rocks or other items can be messy, and it takes a lot of time, which is something that is encouraged in some homes but not in others. At the same time, there is little evidence of exactly how those early formative experiences link to a STEM career or developing an identity as someone who does science. She said that this is an area for gathering better longitudinal data.

Ellenbogen spoke of Robert Tai, at the University of Virginia, who has explored the topic of scientists and their formative experiences. She recommended that participants see Tai's paper titled "Eyeballs in the Fridge"[5] in which Tai discusses very distinct gender differences in what adults in STEM careers point to as a formative moment of "here is what I did as a teenager or youth that pushed me or encouraged me to get into this as a career." The experiences for girls in particular were more about a moment in time that had a particularly affective element to them.

Zero to Five

A question was asked about the type of learning that happens during zero to 5 years old (just a white spot on Figure 2-2). Ellenbogen explained that there is "a significant gap in the science that we know about the development of children at those ages, and what we do as a society to support learners . . . 90 percent of brain development occurs in those years from birth to 5." At the same time, "if you look at the way we support citizens in our society, there is almost no support, or a negligible amount of support for educating zero to 5-year-olds in a way that works with what we know about brain development in those years." According to Ellenbogen, formal schooling for kindergarten and up is typically made smaller or cuter or simpler for those under 5. Brain development research indicates this is not how to develop a good learning experience for a zero to 5-year-old. Ellenbogen suggested reading the "Everyday Science" chapter of the *LSIE* report for more information on education needs of zero to 5-year-olds.

Jeannette Brown commented about early experiences in science. She mentioned that the Chemical Heritage Foundation is collecting video oral histories of women in science, and Brown is also collecting oral histories of African-American women in science. Another resource for oral histories of African-American scientists is the Science Makers,[6] available on the History Makers website[7] (based in Chicago).

Lifelong, Life-Wide, and Life-Deep Learning

Ellenbogen was asked to clarify the distinction between lifelong, life-wide, and life-deep learning and how each needs to be built into effective informal learning projects. She responded that lifelong learning is the most straightforward concept; "from birth to death, you are a learner, and you go through experiences every day that shape the person you are and the way you live your life and the kind of decisions you

---

[5] A.V. Maltese, and R. H. Tai. 2010. Eyeballs in the fridge: Sources of early interest in science. *International Journal of Science Education* 32(5):669-685.

[6] See *www.thehistorymakers.com/biography/category_details.asp?sp=1&category=scienceMakers.*

[7] See *www.thehistorymakers.com/.*

make. The life-wide says you have to jump into that sea of blue and look at what the informal learning experiences are, so what is the width of experiences in addition to the length of it. . . . Life-deep learning is something that is emphasized to help people look more in depth at the kind of world view, the kind of values that shape what people believe. It is a very underresearched area of learning."

The participant then asked, "How do you keep those three ideas in mind when you design something, a learning experience for the museum?"

Ellenbogen explained that museums sometimes do "front-end studies" to find out what the experiences and views of museum visitors are. She stated that "you will see in the *Learning Science and Informal Environments* text that previous experiences are one of the most influential aspects of what people do and experience when they are in any sort of designed environment. You can design all you want, and everyone walks in with a lot of baggage and things that shape the way they see and interpret and experience anything you have designed. The same thing goes for when you look at how multiple people view the same media program."

As an example, Ellenbogen discussed how the Science Museum of Minnesota duplicated a study called the "Six Americas"[8] that looked at national views on climate change. The Six Americas study found that there is a wide range of knowledge and beliefs about climate change, ranging from enthusiastically supporting and accepting the science of climate change to disbelief and rejection. In the middle there is "a disaffected category of, I just don't care about this science stuff."

The museum found that few visitors who took the survey were in the disaffected category, which was lower than the national average in the Six Americas study. It was an expected result though since museums typically attract the science attentive. However, the museum was surprised to find that about 26 percent of visitors surveyed said they do not believe in or accept the science of climate change, which was about the same as the national average.

Research on environmental education shows that values affect a museum visitor's ability to look at the scientific information presented. The Science Museum of Minnesota is looking at how to shift from influencing to informing. Ellenbogen said many informal learning environments are specifically designed to influence someone's views or ideas about science. The Science Museum of Minnesota is grappling with the issue of how to inform people with the kind of science experiences and knowledge that they need and help them understand the ways to make decisions about science in their everyday life.

[8]A. Leiserowitz, E. Maibach, C. Roser-Renoug, and N. Smith. 2010. *Global Warming's Six Americas*. Yale University and George Mason University. New Haven, CT: Yale Project on Climate Change. Available online at *environment.yale.edu/climate/files/SixAmericasJune2010.pdf* (accessed November 5, 2010).

Role Modeling

A participant asked whether there is research on the importance of role models in learning, such as young college women or teenagers leading Girl Scout events, which seem to be very effective in engaging the younger children.

Ellenbogen said the Girl Scouts have good research on this—some is cited in the *LSIE* report. "The interesting thing is that the modeling happens throughout the lifetime. . . . It is one of the most interesting areas that need to be studied across lifelong and life-wide learning. You have so many different kinds of people in your life who model science experiences. You have everything from the kinds of influences you see modeled in television or other sorts of media environments or in books. You also have modeling that happens in the adult-child relationships. There is a significant amount of peer modeling that goes on." Ellenbogen mentioned that Dirk vom Lehn at King's College, London, "has some really great studies of looking at the modeling impact of strangers in designed learning environments."[9]

INFORMAL CHEMISTRY

David Ucko provided some background on the National Science Foundation (NSF) Division of Research and Learning (DRL), which focuses on improving learning and teaching across all ages and all settings, and funds research and development (R&D) grants at about $250 million a year. DRL has four programs, including one focused on informal science education, and is the primary program within the Directorate of Education and Human Resources at NSF that funds furthering public understanding of science and enhancing public science literacy.

Ucko reiterated the point made by Kirsten Ellenbogen—that formal education is critical, "but it only takes up a small portion of one's life." He provided a quote from one of his predecessors at NSF, George Tressel: "Most people, most of the time, learn most of what they know outside the classroom."

Informal learning goes by many other names. Some people call it free-choice learning, experiential learning, or recreational learning. Ucko described informal learning as a pull phenomenon, as opposed to a push phenomenon, because it is driven by the interests of the learner, at a particular time. "It is a voluntary activity," he said.

Ucko illustrated the appeal of informal learning with a quote from Frank Oppenheimer, the creator of the Exploratorium: "No one ever flunks a museum or a television program

[9]For more information, see *www.kcl.ac.uk/schools/sspp/mgmt/people/academic/vomlehn/* (accessed November 5, 2010).

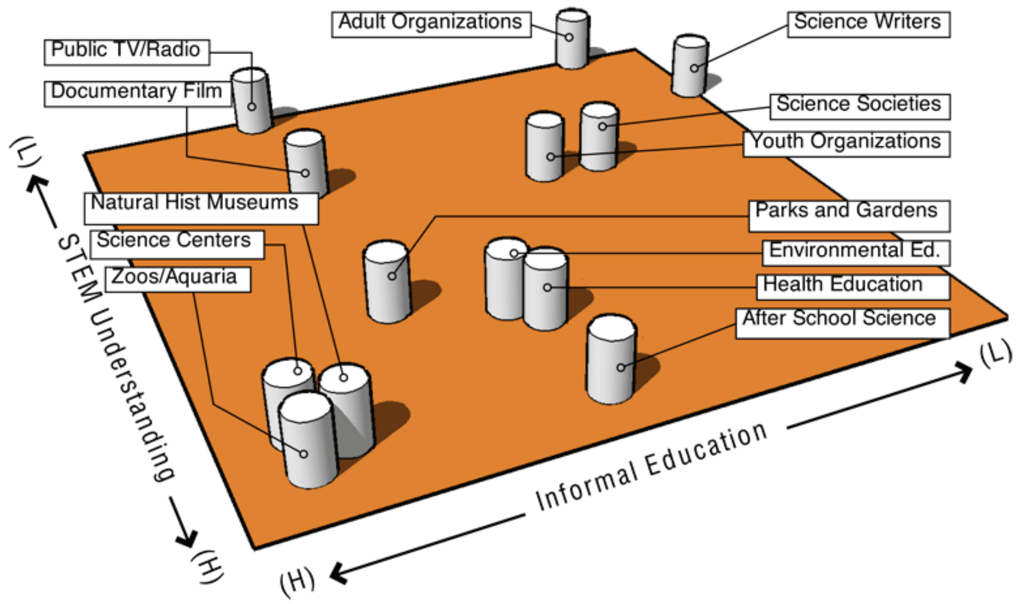


FIGURE 2-3 Informal STEM landscape.
SOURCE: J.H. Falk, S. Randol, and L.D. Dierking. 2008. *The Informal Science Education Landscape: A Preliminary Investigation*. Washington, D.C.: Center for Advancement of Informal Science Education. Available online at *caise.insci.org/uploads/docs/2008_CAISE_Landscape_Study_Report.pdf* (accessed April 6, 2011).

or a library or a park." Ucko spoke of the growth of the field of informal education, which began in the 1970s when the Association of Science and Technology Centers (ASTC) was created. ASTC was founded by 16 members in 1971, and today there are 583 member organizations in 45 countries around the world.

Ucko started in this field about 30 years ago at the Museum of Science and Industry, after teaching at Antioch College. His first professional conference, an ASTC conference, had about 50 people in it. Today those conferences now have about 1,500 people, giving another sense of the growth of the field in the last 30 years.

Landscape of Informal Education

Ucko discussed the landscape of informal education, illustrated by John Falk and others in Figure 2-3. It shows many of the communities and organizations that exist within informal learning, across two dimensions: one promoting STEM understanding and the other practicing informal education. Some groups do more of one than the other, and some sit right at the intersection where education is high in both informal learning and STEM understanding. This appears on the diagram in the corner at the left on the bottom and consists of science museums, natural history museums, zoos, and aquariums. Over the years, NSF has funded all of these organizations and communities to varying degrees to improve the field of informal science education. Ucko discussed some of these approaches to informal education within the context of chemistry in further detail.

Modes of Informal Education and Chemistry

Ucko talked in detail about different types of exhibits as a mode of informal education. These include *permanent exhibits* that stay at a science museum, typically for 5 to 10 years, and then are renewed and replaced; *traveling exhibits* that stay at a museum for about 3 months and then are shipped to another museum for another 3 months; and *mobile exhibits* that travel the country in vans, buses, or other vehicles. Ucko noted that chemistry is not highly represented in most exhibits. However, he was able to provide several examples of NSF-funded exhibits. One example, "Chemistry of Life," was an exhibit at the New York Hall of Science, which still exists and is now called Marvelous Molecules.[10]

Ucko developed an exhibit at the Museum of Science and Industry in Chicago in the mid-1980s, in collaboration with Bassam Shakhashiri and Rodney Shriner at the University of Wisconsin,[11] that was based on basic principles of chemistry

[10]See *www.nyhallsci.org/marvelousmolecules/index.html* (accessed September 13, 2010).

[11]For more recent activities, see Shakhashiri's "Science is Fun" website, *www.scifun.org/* (accessed April 6, 2011).

when applied to everyday life. One example of the many interactive experiments at the exhibit is the electrolysis of water, which "never failed to startle visitors across the hall of the museum when the hydrogen that was formed ignited with spark and created a lot of noise."

One of the challenges Ucko spoke of in trying to present chemistry in an exhibit is conceptual. "It is hard to get people to go from the macro, from what they can see visibly, to the micro." Ucko thinks there are also perception issues; chemistry and the word "chemical" are often equated with toxicity.[12] There are also turf issues: "Things like forensics may be of interest to people, but they may not associate it with chemistry. Same with biochemistry; it might be more linked with biology than with chemistry—and certainly with nanotechnology there is a similar kind of thing going on today." There are also many technical aspects to creating chemistry in these environments. "You need to prepare, you need to get rid of waste, you need to have storage and disposal and maintain things. You have got safety and liability issues, cost and training for the people that are involved in doing this."

Although informal education is becoming increasingly Internet based, he said that TV, radio, and giant-screen films are still important means for reaching people. Two examples of chemistry film projects that NSF has funded recently (both are discussed in detail by Steve Lyons later in this chapter) are:

1. "Lives in Science," in 1999, a grant to WBGH Boston for the NOVA program on Percy Julian, and
2. *The Mystery of Matter: Search for the Elements,* in 2009.

Ucko said that grants for learning technologies (e.g., games) and digital and online media are the fastest-growing piece of the NSF funding portfolio. "We now see aspects of what we call cyber learning in almost every project that we fund." Other areas of informal learning include youth and community programs, which allow time for more intensive personalized learning, unlike an exhibit or digital media setting. After-school programs are probably the most common, but there are also many other targeted kinds of programs.

Also mentioned by Ucko is citizen science, or public participation in science, where the public is involved in making observations, collecting data, and even designing experiments in the real world. This idea started with public participation in bird observations at the Cornell Laboratory of Ornithology in the 1990s.

NSF funds Communicating Research to Public Audiences awards through the Informal Science Education Program. This program allows principal investigators to use part of their research grants to create public learning activities. One example from an NSF Chemistry Division (CHE) funded research grant involved a hands-on activity based on flavonoid plant pigments. He also mentioned that within CHE, broader impacts are required as a review criterion, so many of the research grants have some kind of public activity associated with them as well.

In addition to these kinds of publicly oriented activities, NSF has also tried to advance the field directly through professional development in a variety of ways, such as research and working on infrastructure and capacity building.

Project Evaluation

NSF evaluations of the programs it funds are a critical part of the process. Ucko referenced Kirsten Ellenbogen's talk about front-end evaluation. This evaluation is done at the beginning of a project because of the need to understand who the audience is, what its members are interested in, what they know already, and how to engage them in a particular subject.

He said that while developing a project—when it is still relatively easy to make changes in the project design—it is important to do *formative evaluation*, which involves pilot testing, creating prototypes, et cetera. After pilot testing, there is *remedial evaluation*, which looks at how all of the components of an exhibition work together as a whole and helps identify issues in the project that may need to be altered. NSF requires a *summative evaluation,* which determines whether the project has achieved the impact originally intended. These summations must be posted to a website called *Informalscience.org*, which currently has about 200 examples of summative evaluations for NSF-funded projects.

To help people learn more about these summative evaluations, NSF funded a workshop and published a report called *The Framework for Evaluating Impacts of Informal Science Evaluation*.[13] NSF created categories to characterize the impacts of informal education projects, including awareness, knowledge and understanding, engagement, attitude, and behavior skills.

Ucko also highlighted key aspects of the *LSIE* report and its importance to the education community, as listed below:

1. *Broaden the definition of learning*. Typically learning is defined as what happens at school. By adding items 1 and 6 (see Box 2-1) to the strands of learning, it "extended the definition of learning beyond the cognitive, to talk about interest and motivation and to talk about identity formation."
2. *Provide a foundation for future research*. The *LSIE* report is a synthesis of what has been done in research and evaluation across informal learning, drawn from many subdisciplines. By making this work known and by making rec-

[12]In this report, chemistry is defined as the science of composition, structure, and properties of substances (chemicals) and the changes they undergo.

[13]For more information, see *caise.insci.org/uploads/docs/Eval_Framework.pdf* (accessed November 10, 2010).

ommendations, it provides a foundation for future research and expansion of the data.

3. *Provide a guide for practitioners*. It is a way for them to take what has been learned about the research in informal learning and apply it to their everyday work.

Ucko described the Nanoscale Informal Science Education (NISE) Network.[14] Now in its fifth year, it is the largest project that NSF has funded in recent years and is a $20 million 5-year effort. It is led by the Museum of Science in Boston, and includes the Science Museum of Minnesota, the Exploratorium in San Francisco, and many others. NISE brings together science museums around the country with nanoscience and technology researchers, to develop exhibit elements, programs, public forums, and a variety of products designed to increase public awareness and understanding of nanoscience and technology. Everything is being developed as open source materials, so they can be shared freely and to avoid duplication.

Another NSF effort to fund informal learning is the Center for Advancement of Informal Science Education, CAISE.[15] It is designed to serve the field overall and to help create a community of practitioners across those different dimensions of informal learning discussed earlier in the landscape study. Ucko believes that these activities are helping the field of informal science education to reach greater recognition of its impact and public engagement, for example:

- *Nature* had an editorial recently called "Learning in the Wild" about the impact of informal science education.
- Professional organizations such as the National Science Teachers Association have an informal science day as a part of their activities every year.
- Private foundations such as the Noyce Foundation are increasingly funding informal learning.
- There was recently a House subcommittee hearing on Beyond the Classroom: Informal STEM Education.
- NSF recently held an Informal Science Education summit that brought together 450 people from across the field.

Ucko provided a few suggestions for how chemists can take advantage of informal education resources and opportunities:

1. *Start with the learner, not with the contact.* Start with what is going to engage the learner; or the "hook." He highlighted the work of Matt Nisbet at American University,[16] who has written about framing, which takes into account the audience's values, knowledge, and attitude when one tries to engage the public.

2. *Create learning experiences that are engaging.* Studies from Robert Tai and others show that many scientists knew they wanted to be scientists by ages 12 to 14, so it is important to engage children early. However, Ucko cautioned that it is important that these efforts be done in ways that are not overly promotion oriented.

3. *Build on the research and practice.* Ucko encouraged participants to build on the NRC *LSIE* report and to think about the lifelong learning ecology and the web of experiences that span settings and time. He believes creating a network of people interested in informal learning about chemistry would help leverage the existing infrastructure and resources.

4. *Research and evaluate efforts.* Ucko believes that continuing research and evaluation of projects related to informal learning are the only ways to add to the knowledge base and continue support for informal education.

Questions and Answers

Chemistry in Museums

A participant noted that in addition to the list of museum chemistry exhibits that Ucko mentioned having, the Museum of Natural History has one called Science in American Life that is sponsored by the American Chemical Society. The exhibit also has a room of hands-on activities geared toward young kids.

Mark Cardillo mentioned that the Dreyfus Foundation has a seed program that supports museum exhibits in chemistry. He noted that many of the exhibits mentioned by Ucko and others were initiated with a seed grant.

NISE Network

Participant Dr. Rosenberg asked Ucko about the effectiveness of the NISE Network in incorporating chemistry.

Ucko believes it has been effective and has grown substantially. For example, almost 200 science museums around the country have an event each year called Nano Days. The NISE Network creates effective kinds of learning experiences by bringing museums together and linking them to researchers and could be a useful model for other organizations.

Ellenbogen noted that there would be a report[17] available September 30, 2010, that summarizes the chemistry experiences in NISE programs and exhibits.

[14]For more information, see *www.nisenet.org* (accessed September 13, 2010).

[15]For more information, see *caise.insci.org* (accessed November 10, 2010).

[16]For more information, see *www.american.edu/soc/faculty/nisbet.cfm* (accessed September 13, 2010).

[17]For more information, see the NISE Network Research and Evaluation website at *www.nisenet.org/catalog/eval* (accessed November 11, 2010).

FIGURE 2-4 Dreyfus Foundation-funded energy exhibit at the Museum of Science, Boston.
SOURCE: 2010. Printed with permission, MJ Morse, Museum of Science, Boston.

NSF Broader Impacts

Another participant commented that NSF broader impacts grants seem like a good opportunity for collaboration among chemists and informal science educators, because the recipients of these grants are chemical researchers, who "don't really know that much about how to reach out to the public. Yet there is this whole population of people who do just that, and they are not connected to each other."

Ucko said NSF encourages chemistry principal investigators (PIs) to collaborate with people from the informal science education communities in advance. Unfortunately, he has heard that PIs will often ask for a letter of support from a museum or education expert the day before the proposal is due to NSF, which does not lead to effective collaboration.

Opportunities for Chemistry in Informal Education

Ellenbogen asked Ucko to speak about the compelling areas of chemistry that might benefit from or be well suited to informal science education. Ucko warned against starting from chemistry and suggested instead planning an informal education activity based on real-world topics that typically interest people, such as environment, food, or health, and then address the chemical aspect. The topics can be identified from front-end testing (as mentioned earlier by Ellenbogen) or by surveying the intended audience before planning an activity.

Mark Cardillo mentioned two new Dreyfus-funded chemistry exhibits, one at the Science Museum in Boston (Figure 2-4)[18] and one at the Museum of Science and Industry in Chicago.[19] The Museum of Science and Industry in Chicago in particular has developed a new and exciting multimillion-dollar Science Hall.

CHEMISTRY, THE NEGLECTED SCIENCE

Stephen Lyons explained that his interest in science communication stems from producing the program *Forgotten Genius* (mentioned earlier by David Ucko), a 2-hour biography of the African-American chemist Percy Julian (Figure 2-5), which aired on the PBS NOVA program 3 years ago.[20] He explained that "Julian's scientific career involved a lot of

[18]The exhibit is called "Fuel Your Future." For more information, see the Museum of Science Boston website at *www.mos.org/* (accessed November 11, 2010).

[19]The exhibit is called "Create a Chemical Reaction." It is part of the larger, recently opened Science Storms exhibit. See *www.msichicago.org/whats-here/exhibits/science-storms/the-exhibit/atoms/create-a-chemical-reaction/* (accessed September 13, 2010).

[20]For more information, see the PBS Forgotten Genius website at *www.pbs.org/wgbh/nova/julian/* (accessed September 10, 2010).

pretty amazing chemistry, including his landmark synthesis of a glaucoma drug called physostigmine, and his pioneering work trying to make cortisone and other steroids available to people at reasonable prices. On the strength of this work, Julian was elected to the National Academy of Sciences. He was the first black chemist elected to the Academies."

Lyons described how he came away from the project with two lessons about communicating chemistry topics. "Lesson number one was that chemistry can make interesting television." As he began to look deeper into Julian's work, he was fascinated by the chemist's ability to manipulate tiny bits of matter, to work with atoms that he could not see or touch, but was then able to rearrange them to make molecules that could improve peoples' lives. Lyons described this as "almost magical," and a very interesting topic for a television documentary.

The second lesson was that chemistry was not being covered on television. "I looked around and I discovered that I essentially had the whole field to myself; no other television producers were interested in making television on chemistry."

FIGURE 2-5 Chemist Percy Julian, winner of the Spingarn Medal in 1947.
SOURCE: Percy L. Julian, Scurlock Studio Records, Archives Center, National Museum of American History, Smithsonian Institution.

FIGURE 2-6 Marie Curie is one of the personalities to be featured in the Lyons-Moreno film *The Mystery of Matter: Search for the Elements*.
SOURCE: U.S. National Library of Medicine, History of Medicine Division.

Chemistry Can Make Interesting Television

Lyons has found two things that make chemistry interesting to people: making the program about people, and showing why it matters. This was relatively easy in the case of *Forgotten Genius*, because Julian's life story was so compelling: he had a lifelong battle against racism, worked hard to become a chemist, and used chemistry to help people.

Lyons applied what he learned from *Forgotten Genius* to his new video production titled *The Mystery of Matter: Search for the Elements.* This is a 2-hour special focusing on the human story behind the development of the Periodic Table (Figure 2-6).[21]

Many people are familiar with the Periodic Table, because it hangs in almost every chemistry class in the world. However, there is an incredible story that very few people know behind the rows and columns of elements. There was a long quest to discover the elements and to define and explain the hidden order among them. Lyons described this quest as

[21]For more information, see *informalscience.org/project/show/1892.*

one of the great adventures in the history of science, filled with fascinating characters. For example, there was Dmitri Mendeleev, a Russian chemistry professor whose struggle to organize a textbook led him to devise the Periodic Table in 1869; Joseph Priestley, who discovered oxygen; Marie Curie, a Polish graduate student who launched the science of radioactivity and used it as a tool for finding new elements; Harry Moseley, a young Englishman who used the new tool of X rays to redefine the very nature of elements, only to die at age 27 in World War I; and Glenn Seaborg, whose discovery of plutonium played a key role in ending World War II and who went on to pioneer the creation of elements beyond uranium in the Periodic Table.

In producing *Search for the Elements*, the production team plans to use many of the same techniques as in the Julian film. Actors play the key characters, delivering lines drawn from the scientists' own writings, historians, biographers, chemists, and writers who helped tell the story, and there will be dramatic reenactments of key discoveries with period lab equipment. However, instead of focusing on one scientist as was done in the Julian film, *Search for the Elements* will be an ensemble drama about the collective effort to understand the nature of matter, about a series of individual discoveries that gradually built a foundation of knowledge.

The program will also show how modern scientists continue to build on that foundation, conducting new chemical research that may affect peoples' lives in profound ways. For example, the film will highlight the work of Massachusetts Institute of Technology (MIT) chemist Daniel Nocera. For years, Nocera has been searching for an element that could serve as a catalyst to speed up the splitting of water into oxygen and hydrogen, which could then be used as a clean-burning fuel. Even though the Periodic Table was invented more than a century ago by Mendeleev, it has led to modern chemical research that may one day help the world's energy problems. Thus, the film relates chemistry to renewable energy, a topic that resonates with many people.

Lyons noted that his production team received a critical NSF planning grant to help this project last year and has also received support from the Dreyfus Foundation, the Haas Trusts, and the Chemical Heritage Foundation. At the time of the workshop, NSF was considering his proposal for production funds. The funding has since been received, and Lyons hopes to produce the film in time for broadcast on PBS late in 2011 during the International Year of Chemistry.

In addition to the television program, the project will include an extensive outreach program involving the St. Louis Science Center and its Yes Teens program. The American Chemical Society has pledged to make *Search for the Elements* the focus of National Chemistry Week, and a special teacher's edition DVD of the program will be produced with many extra features to help teachers use the human stories behind chemistry to educate their students.

Chemistry, the Neglected Science

Lyons elaborated on the second lesson he drew from the Julian project: little chemistry is highlighted on television. By reviewing the previous 12 years of NOVA programs, he found that the most popular category was "history mystery." In this category, the producer uses science to explore a historical mystery, such as the Kennedy assassination. However, only one film out of the 190 broadcasts focused specifically on chemistry, which is lower than all other areas of science.

He noted, however, that the data he collected are a few years old, so they do not reflect the most recent programs in the NOVA schedule. For example, there have been a few short pieces about chemistry on NOVA's summertime magazine program, *Science Now*, but no full-length films since *Forgotten Genius*. Also, he did not take into account bits of chemistry in many other films, such as those on molecular biology, global warming, and forensics. Some people might also quarrel with his categorizations, such as two science programs near the bottom of his list on artificial diamonds and the samurai sword, which he categorized as material science. Both concern the structure of matter. However, "if you put them in the chemistry column, chemistry jumps right up over math and botany."

Lyons reviewed the programs through NOVA's 36-year history and only found 6 programs out of a total of approximately 690 that were clearly and primarily about chemistry:

- *Forgotten Genius* (2007)
- *Race to Catch a Buckyball* (1995)
- *Hidden Power of Plants* (1987)
- *Plague on Our Children* (1979)
- *A Pill for the People* (1977)
- *Linus Pauling: Crusading Scientist* (1977)

However, he said NOVA is not alone. If other programs, for example, on the Discovery Channel could be searched, "I'm sure we would find the same pattern there. In fact, there is even less chemistry on other networks than there is on PBS."

Similar results were found when he reviewed other popular media, such as books, newspapers, and magazines. There are recent popular books on chemistry, such as Oliver Sacks' *Uncle Tungsten,*[22] Philip Ball's *H_2O,*[23] and John Emsley's *Molecules of Murder*.[24] Lyons noted that compared to many other sciences, these writers and books are rare.

Lyons cautioned that his investigation was not a systematic survey of how chemistry is covered by the media. He

[22] O.W. Sacks. 2001. *Uncle Tungsten: Memories of a Chemical Boyhood.* New York: Alfred A. Knopf.

[23] P. Ball. 1999 *H_2O: A Biography of Water*. London: Weidenfeld & Nicolson Ltd.

[24] J. Emsley. 2008. *Molecules of Murder: Criminal Molecules and Classic Cases.* London: Royal Society of Chemistry.

wanted to get a quick sense of chemistry's media profile by looking at limited samples of a few key representatives of the various media. Lyons believes it would be useful if somebody could do a more thorough study than this. "Still, the pattern seems clear. Given the huge number of chemists in the world, the amount of science they do, and the enormous impact it has on our lives, the lack of attention from the mainstream media is extraordinary. That is why I call chemistry a neglected science."

Lyons said he is puzzled by writers' and TV producers' avoidance of chemistry. One common explanation is that chemists do not communicate information about their fields effectively. However it is clear from the Julian film that there are many articulate chemists. Lyons also suggested that many people are discouraged by their high school chemistry experiences. "There is some truth in this, because badly taught chemistry has left a lot of people—writers and TV producers included—with a lasting aversion to chemistry."

Another factor often cited is that chemistry is hard to visualize, because it occurs at the molecular level. This is a handicap for filmmakers, but it has not stopped producers from making films about the Big Bang, black holes, superstrings, and many other equally invisible things in physics.

Lyons thinks the main reason chemistry has been neglected by popular media relates to the types of problems studied by chemists. From the media's point of view, science is only as interesting as the questions it asks, such as: What is the origin of the universe? What accounts for the rise and fall of ancient civilizations? Can we keep the planet from overheating? What can we learn about ourselves from studying animal behavior? Can we find cures for AIDS or cancer? These are some of the questions pursued by scientists in cosmology, archeology, ecology, biology, and medicine—big captivating questions of interest to everyone. These questions make good subjects for books, articles, and TV programs.

Lyons thinks chemists have not been good about articulating those big questions. Many chemists seem to be focused on fairly narrow technical questions, not the kinds of big questions that captivate a television audience or excite a science writer. When they do have a discovery that might be of great public interest, many chemists are not very good at letting the world know about it. Biologists and physicists may not be any more articulate than chemists, but they are more practiced when it comes to public relations and promoting their work.

Lyons said that chemists are probably not going to change the nature of their research just to get more media attention, nor should they. However, if they are doing research that is potentially of interest to people outside their field, they can frame it in terms broad enough to appeal to the public. They could work with their institutions' news offices to reach out to the media, as well as put in time working with writers and TV producers to make the stories as accurate and interesting as possible.

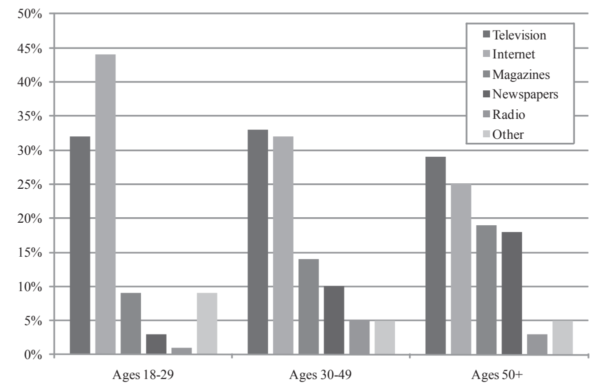


FIGURE 2-7 Media sources used by American (home broadband Internet users) to obtain most of their science news and information, grouped by age. The *y* axis is the percentage of those surveyed. SOURCE: John Horrigan. 2006. *The Internet as a Resource for News and Information about Science*. Washington, DC: Pew Internet & American Life Project. Available online at *www.pewinternet.org* (accessed December 28, 2010).

Lyons spent the rest of his talk discussing two things that he thinks can have an even greater impact on improving chemistry communications: (1) exploiting the Internet and (2) capitalizing on chemistry's financial resources.

He explained how the sources for news and science information have changed over the past 10 years. For example, the Pew Research Center on the People and the Press found that television continues to be the main source of news for Americans.[25] However, the percentage of those who obtain news from television, newspapers, and radio has declined, while the proportion obtaining news from the Internet has grown dramatically, passing all other sources except for local TV. This trend is also seen in the media sources Americans use to get news and information about science in particular. The Pew Research Center also found that 40 million, or 20 percent, of Americans now rely on the Internet as their primary source for science news. Only television ranks higher at 41 percent.

Lyons said this trend is even more pronounced among young people with broadband access, as shown in Figure 2-7. Among those ages 18 to 29, 44 percent said they accessed most of their science information from the Internet, surpassing television, and far outstripping all the other sources. When asked which news source they go to first for science information, 76 percent of high-speed-connection users in this age group said they turn to the Internet. All other sources combined totaled only 17 percent.

[25] John Horrigan. 2006. *The Internet as a Resource for News and Information about Science*. Washington, DC: Pew Internet & American Life Project. Available online at *www.pewinternet.org/~/media//Files/Reports/2006/PIP_Exploratorium_Science.pdf.* (accessed December 28, 2010).

Lyons said, "Clearly if the chemistry community's goal is to communicate more effectively with young people, the Internet must be part of the strategy." One potentially powerful tool for exploiting the Internet is video. For example, since its founding 5 years ago, YouTube has come to dominate the market with its eclectic mix of mostly amateur videos and clips from movies, TV shows, and music videos. However, the last 2 years has seen the emergence of another subtler trend, a growing number of high-quality videos created specifically for the Internet. In 2008, the *New York Times* reported that more and more office workers are using their lunch hours to watch short videos over the Internet, "video snacking."

He noted that the explosion of Internet video is a tremendous opportunity for the science community. It offers a new channel for delivering scientific research news directly to the public without the barriers imposed by the broadcast media. There have been a few small steps in this direction, simple video podcasts by journals such as *Nature* and isolated videos produced by museums and others. However, he said video producers and the scientific community have barely begun to tap the promise of this new medium.

Lyons described his effort of 2 years ago, with support from the Dreyfus Foundation, in which his company produced a short online video on the water-splitting catalyst discovered by Dan Nocera at MIT. Because Nocera told him about the catalyst soon after its discovery, Lyons' company was able to produce the video and have it ready to stream just a few days after Nocera's paper was published in *Science*. They posted it on Blip.TV,[26] a service that offers free video distribution on the web.

The viewership for the video started small but grew rapidly after being noted by the *Chemical Engineering News* blog master. Following that reaction, *Wired Science* gave it a positive review as well. This public exposure seems to be the reason viewership increased twentyfold overnight. All of this Internet traffic moved the water-splitting catalyst video onto the front page at Blip, where still more people viewed it. After 5 days it was one of the most viewed videos on the site.

This experience illustrates one of the main attractions of Internet videos—the ease with which they can be disseminated, Lyons said. This video can now be viewed on many websites, including at the Chemical Heritage Foundation, the Dreyfus Foundation, MIT, NSF, and others. Understandably, he said viewer traffic for the video decreased after the initial excitement over the catalyst discovery, yet 9 months later, people were still watching. Lyons estimated that the video has now been seen by 20,000 to 30,000 people. He noted however that this is trivial compared to chemistry-related videos that have gone "viral," such as the well known Diet Coke and Mentos geyser (ultrasonic soda fountain) video,[27] shown in Figure 2-8, which at the time of this workshop had 9 million viewers. He said his effort was not bad for a little video launched into cyberspace with no real publicity, but a series of chemistry videos with a regular home on the Internet where people knew to look for them would probably do much better.

Based on teacher response to the first video he made, Lyons thinks such videos could be widely used in classrooms. He said chemistry teachers are hungry for video sources, particularly those that show chemistry at work today.

In producing this online chemistry video, Lyon's approach was to treat it like a television magazine piece, yet keep the budget as low as possible. However, he said there are many other potential ways to produce chemistry videos for the web, although there are no standards or rules. Internet video is still new, so nobody knows the best approach.

Lyons encouraged the chemistry community to embrace video and experiment with it to see what works best. He said the Internet offers a way to bypass media gatekeepers and get the content out to audiences that would like to see it. In the process, chemistry can be a real leader, showing scientists in other fields how they can use this new medium to reach young people in creative ways.

Lyons finished his talk by highlighting chemistry's unique position among the sciences. It is the foundation of a large and profitable industry, which sets it apart from other fields of science. He speculated that if the chemistry community chose to, it could pool its resources to create a fund to bring about greater coverage of chemistry, what he referred to as the "Chemistry in Media Fund." For example, if 10 donors gave $250,000 a year, it would provide an annual fund of $2.5 million, which could be used to support chemistry communications in all media sources. He said, "The result would profoundly change the landscape, giving chemistry a much higher profile in the popular media than it has now."

With science journalism in peril, people have begun to explore new business models that would allow it to survive in a different form. One example Lyons gave is the organization Pro Publica,[28] which pursues public interest investigative journalism and is supported by a group of philanthropic organizations including the MacArthur Foundation. Another example is a service called Kaiser Health News,[29] launched by the Kaiser Family Foundation. Run by a former National Cancer Institute science editor, it provides impartial coverage of health care issues. As the old advertising- and subscrip-

[26]See *www.blip.tv/file/1144655/* (accessed December 28, 2010).

[27]See *www.youtube.com/watch?v=hKoB0MHVBvM*; 12,657,015 as of November 11, 2010; also featured by Time Online at *www.time.com/time/specials/packages/article/0,28804,1974961_1974925_1973107,00.html*.

[28]For more information, see *www.propublica.org/* (accessed December 28, 2010).

[29]For more information, see *www.kaiserhealthnews.org/* (accessed December 28, 2010).

FIGURE 2-8 YouTube favorite, the "Diet Coke + Mentos" geyser. Mentos candies are dropped in bottles of diet coke soda, causing a rapid-foaming chemical reaction that shoots into the air like a geyser or fountain. Video available at *www.youtube.com/watch?v=hKoB0MHVBvM*
SOURCE: Diet Coke and Mentos Fountain. Photo courtesy of EepyBird.com.

tion-based business model crumbles, people in the media are looking for new means of support. Philanthropy is emerging as a strong contender. In this new climate, Lyons thinks the media would be receptive to support from the chemistry and media fund, as long as the funds are used to support solid impartial science journalism.

Lyons said that this is a good opportunity for the chemistry community, because it may be the best way to improve public understanding of chemistry and enhance appreciation of the chemical enterprise. He said, "Today many Americans come out of school with both a poor understanding of basic chemical concepts and a negative attitude toward chemistry. The only way the chemistry community can turn this around, short of an overhaul of chemistry education, which is a subject for another day, is to tap the one remaining conduit for science learning, informal education."

In the first year alone, the chemistry and media fund might support a mixture of chemical communications. Over time, by supporting a wide array of informal science education initiatives, Lyons thinks the fund would do more to enhance public understanding of, and appreciation for, the field than all the image advertising the chemistry industry now invests in, and at a small fraction of the costs.

Lyons said he has spent a lot of time talking with chemists over the last few years, and his sense is that chemists feel neglected by the press. They feel most people do not understand or appreciate what they do. They have a story to tell, just as other scientists do, but for some reason their story is not getting out there, and this bothers them. From his perspective as an outside observer, this seems like an important problem and one the chemistry community needs to confront, understand, and address. He thought the workshop might be an important step in that direction.

Questions and Answers

Jeannette Brown thanked Steve Lyons for the Percy Julian film, which she noted "is the only film that shows African-American chemists." She mentioned that the ACS Committee on Minority Affairs and the Women Chemists Committee are now working hard to start another film about Dr. Marie Daly, who was the first African-American woman to get a Ph.D. in chemistry. Brown further commented about the need that exists for more materials about other underrepresented minorities, such as Hispanic and Native American chemists, and how useful it would be to have those materials available on the Internet.

Steve Lyons responded that one of the most rewarding things about the Julian project was having the chance, with the support of the Dreyfus Foundation, to go out and interview 60 people who knew Julian. Lyons and his team gathered information about Julian's life and his scientific career that would have otherwise been lost, making it a very rewarding experience.

Lyons also agreed with Brown that her Daly project would be ideal for the Internet, because more and more teachers are looking online for educational materials. He said if she could help produce a series of short videos about African-American women in chemistry and African-Americans in other fields of science as well, they would be widely used. He cautioned that videos should be kept short though, because that is what most Internet users have grown accustomed to.

OPEN DISCUSSION 1

David Ucko commented about NSF funding. He encouraged those with good ideas to bring them to NSF. He said, "We can only fund things that we get proposals for. So I would encourage folks to develop proposals for informal science education in chemistry."

Bill Carroll commented that one of the difficulties in chemistry is counterbalancing the negative images. For example, he said, "If you cure someone it is medicine, if you poison someone, it is chemistry. It is almost as though you have to undo that first."

Lyons agreed and said the best way he sees to address the problem from the point of view of the media is to continually show how chemistry is used through the stories of individual people. Gradually, it will help people to see chemists in a different way. He said people generally have no idea what chemists actually do in their work, so it would be useful to provide stories of their lives as a series of videos on a television program or an online series of videos. His video about Dan Nocera is a good example of showing the story of a chemist, how Nocera set out working for 20 years to address the energy problem. A series of those kinds of examples would help people to see chemistry in a new and more positive way.

Mark Griep from the University of Nebraska asked about the use of chemical symbols and formulas in communicating chemistry to the public, such as the structure of physostigmine in the Percy Julian film.

Ucko responded that in a museum, visitors come from many different backgrounds. They range from people who know nothing about chemistry and would never recognize a chemical symbol at all, to others who are Ph.D. chemists, so there need to be varying degrees of content that support the experience. He suggested that chemical symbols not be the starting point for engaging the public. He said the symbol is often secondary to what the work of the chemist is really about, so it can be there at some point in the exhibit for those that would understand what it is or those who want to learn more.

Lyons added that it is different in television. In the Percy Julian documentary, the use of letter symbols for chemicals was avoided entirely. There was not a single frame in the entire film that showed a chemical formula. Instead of using symbols, they used a simple ball and stick illustration to help people understand the chemicals. An explanation was provided for the basic steroid structure of physostigmine and how it could be modified by adding and subtracting pieces on the end of the structure. It was a very important concept in understanding Julian's work, and it was also simple enough for people to grasp. He explained how even if the audience did not understand the details, they could get the idea that the properties of molecule could be changed by adding different pieces in different places.

3

Chemistry in Print

"Assume you are writing for someone with a degree in history."
–John Emsley

As pointed out earlier in the workshop and highlighted elsewhere,[1] the primary source of current news events and science and technology information for most people in the United States today is the Internet and television. At the same time, many people continue to look to newspapers, magazines, and books (print media) for this type of information. In this session, speakers discussed the strengths and weaknesses of communicating chemistry and science using print media and the ways traditional print media are evolving to meet the growing demand for Internet content. **John Emsley** from the University of Cambridge discussed steps to becoming a science writer. **Ivan Amato** of the Pew Charitable Trusts discussed the opportunities that exist to highlight chemistry. **Joy Moore** from Seed Media Group provided insights using print media and science blogs to promote a better understanding of chemistry.

WRITING ABOUT CHEMISTRY

John Emsley started this session focusing on popular science writing and chemistry. For those just starting out in this area, he said to write for college magazines or company newsletters, "for the love of the thing, not for any money." After building up a portfolio, one can then approach publications that will pay for the articles, such as local newspapers and popular science magazines. After working through these steps, he eventually had a column in a national British newspaper called "Molecule of the Month." Later (about 15 years ago), he was approached to write books. "If you want to become a popular science writer, don't try and run before you can walk," Emsley cautioned. He emphasized the need to build up a portfolio of work before attempting to jump into writing a book.

Emsley explained that there are two kinds of science books, those for an academic audience and those for a general audience. Academic books are printed in small numbers (fewer than 1,000) and are for readers who are looking for specialist knowledge. General audience books are printed on a large scale for readers who want to know more about the subject and to be entertained while reading about it. One of the books Emsley wrote, *Molecules of Murder,* was the result of prompting from his agent. He suggested that Emsley combine popular science and true crime to appeal to a general audience. As a result of that prompting, Emsley ended up writing two books, one called *Elements of Murder* and one called *Molecules of Murder*, which are two of his best-selling books.

"Don't Give up Your Day Job Just Yet"

Emsley talked about what he thinks prevents chemists and other scientists from becoming popular science writers. One factor is the adverse effect it can have on one's career. Some people in an academic department may view it as taking away from research activities. Another contributing factor is the difficulty scientists have expressing ideas in very simple terms. They are afraid of putting things in print and making mistakes, because people will remember those rather than remember the good points. Another barrier to becoming a popular science writer may be what Emsley calls the "sneers of your peers." Once those barriers are overcome, it is then possible to think about writing.

Emsley spoke about the common mistakes new writers make. One is assuming the audience is knowledgeable about the material covered. The audience may not understand all

[1]For more information, see National Science Board. 2008. *Science and Engineering Indicators*. Arlington, VA: Division of Science Resources Statistics, National Science Foundation. Available at *http://www.nsf.gov/statistics/seind08/c7/c7s1.htm* and The Pew Internet and American Life Project at *http://www.pewinternet.org/*.

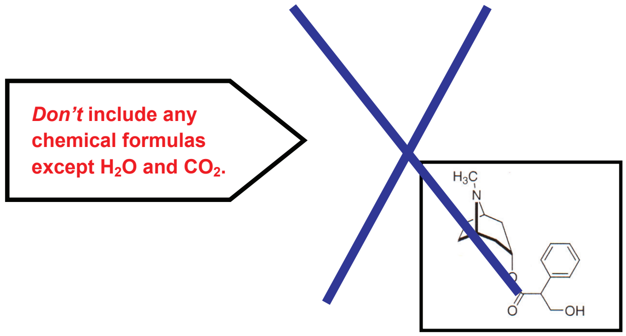


FIGURE 3-1 Advice from John Emsley about including chemical formulas in science writing.
SOURCE: John Emsley, University of Cambridge.

the technical words or be interested in having all the details carefully spelled out. There really is no time to do that in popular writing, because "you have got to keep the story flowing, you have got to carry people with you."

Emsley strongly advised not using technical terms. If it is necessary to use a technical word, then the next word in the sentence has to explain what it is. For example, rather than saying nuclear magnetic resonance, it would be better to say it is a magnetic technique used to determine chemical structures. He also said not to include complex chemical formulas in writing, such as shown in Figure 3-1. He said that structures such as H_2O and CO_2 are fine, but nothing more sophisticated than that should be used. Otherwise, most readers will not understand it and will tend to stop reading at that point.

Emsley cautioned—as many in journalism do—not to overestimate peoples' chemical knowledge, but also not to underestimate their intelligence. He also said not to expect people will read every written word. He said he was told when he was a newspaper writer, "Assume you are writing for someone who has got a degree in history, who is no scientist." A writer also should not assume that people read every word of an article. He said, "Tell the beginning of the story quickly, tell the whole story quickly, and then go into depth later on." Many people never get past reading the headline of a newspaper article.

Emsley provided some insights on choosing what to write about. He said people want to read about something that is new. They like something that is an answer to a previously unsolved problem or that overturns a widely held belief. They like a news item that promises a better future or appeals to national pride. One place to look for ideas is in areas where chemistry is important to people's lives. While writing for magazines and newspapers, he would look through the short papers at the back of the *Journal of the American Cancer Society*. He suggested approaching an editor and saying, "I have just read this, do you want me to write something?" Other "hooks on which you hang a story" that he mentioned included sex, health and money, discovery and novelty, danger and confrontation, and national benefit.

Commenting on how to make chemistry interesting to a nonscientist, Emsley said that it is important to include a lot of human interest information. "The general reader is looking to read about people rather than things," he said. For example, when talking about a research finding, it is good to give the names of the researchers, their status, age, where they work, and their role in the study.

Emsley ended his remarks with this: "It is difficult to start out writing. When I lecture students at Cambridge, I always end up saying, become a writer, but don't give up your day job just yet."

RESPECT FOR CHEMISTRY

Ivan Amato elaborated on the reasons he thinks the field of chemistry does not get the attention it deserves:

1. *Chemistry is the back story.* For example, stories written about pharmaceutical drugs tend to focus on the impact of the drug, such as saving a person's life, rather than about the brilliant chemistry and reaction discovery that went into putting that drug into the hands of a physician.
2. *Chemistry is hard.* Amato said, "Chemistry is why so many pre-meds do not go on to medical school. It is the thing that took the 4.0 or 3.5 [grade point average] down to 2.5." Chemistry is often thought of as being hard and not the most enjoyable experience, rather than something that is fun and interesting.
3. *Chemistry is invisible.* While chemistry is everywhere, in materials, medicines, fuels, and more, it tends to go unnoticed by most nonscientists. "The molecular bases of things are invisible and they are a harder thing to talk about than looking up at night at the stars or a medical drama where there is life and death," said Amato.
4. *Chemistry is an umbrella term.* Chemistry covers many areas of specialization that are not always identified as chemistry. Areas under the disciplinary umbrella of chemistry can also be somewhat disparate, such as polymer chemistry and biological chemistry.
5. *Chemistry is an arcane language.* Talking about chemistry can be like talking in a foreign language. Amato said, "I think it is very hard for the chemistry community or for anyone who gets close and works with this language all the time to keep it in mind."
6. *Chemists are culturally biased against publicity.* This is not peculiar to chemistry, but it is a cultural issue that comes both from the science community and from the editors and the editorial boards of journals. There seems to be a sense of power that comes from using tough language that only specialists can understand.

BOX 3-1 MEN AND MOLECULES
by Roald Hoffmann

Cantilevered methyl groups,
battered in endless anharmonic motion.
A molecule swims,
dispersing its functionality,
scattering its reactive centers.
Not every collision,
not every punctilious trajectory
by which billiard-ball complexes
arrive at their calculable meeting places
leads to reaction.
Most encounters end in
a harmless sideways swipe.
An exchange of momentum,
a mere deflection.
And so it is for us.
The hard knock must be just right.
The eyes need lock, and
glimmers of intent penetrate.
The setting counts.
A soft brush of mohair
or touch of hand.
A perfumed breeze.
Men (and women) are not
as different from molecules
as they think.

SOURCE: Printed with permission of Roald Hoffman.

In Awe of Chemistry

Amato then proposed that one way to counteract the negative views is for chemists to celebrate and draw more attention to the Periodic Table of Elements. For example, he highlighted Theodore Gray's elaborately detailed wooden Periodic Table.[2] When Amato looks at the Periodic Table, he feels a sense of awe. He said, "It is a magnificent thing. If you think about what this is representing, not only is it an incredible consolidation of a vast amount of scientific research and discovery and intellectual effort and brilliance, but it is a representation in some ways of everything that ever was, is, or will be. That is a very awesome thing."

However, the chemistry community squanders that opportunity. Amato explained, "[The periodic table] is all of the Hubble images of astronomy, right there, for the chemistry community, if a certain kind of language and ways of thinking about it and embracing it can be worked on." He shared poetry about the Periodic Table. He wrote a poem called *God's Table*.[3] Chemistry Nobel laureate Roald Hoffmann has also written a poem titled "Men and Molecules" (Box 3-1).[4] Amato described the Periodic Table as a "mandala of creation. It is every color, every texture. It is an encryption of everything that ever was, is, or will be." He said "teachers should tell students to take off their goggles and gloves and stare at the table," and the table should be "set in a rococo frame, gold leafed and intricate, flanked by candles day and night, never coiled up like a window shade, unfurled merely for academic reference."

Amato explained that poetry is hardly tapped as a way to communicate chemistry. When Amato was with the American Chemical Society (ACS), Hoffmann actually did a poetry reading at an ACS national meeting in the McCormick Exhibition Convention Hall in Chicago. Amato described how Hoffmann was surrounded by analytical instruments, mass spectrometers, spectrophotometers, glassware, pipettes, and other displays, and "in a tiny part of real estate in the vast Convention Hall of the ACS meeting, there were about 200 people, standing room only, listening to Roald Hoffmann talk about chemistry with emotion."

Amato emphasized the idea that chemistry is in culture, not apart from it, and that it really is all around us. He said that "we don't actually have to reinvent the wheel, although that is fun to do and I think we should try. There are examples out there that should be inspirational. I love this idea of a hugely corporate funded reservoir of money [proposed earlier by Stephen Lyons] for creative people to begin to follow through on some of these examples."

Amato discussed examples of chemistry in the cinema. One of his favorite movies from 1940 is *The Man in the White Suit*, in which the main character invents a new polymer that can be turned into a fiber for making a perfect fabric that never wrinkles and never stains. Another movie is *Lorenzo's Oil*, which Amato described as a "great human" and "chemistry-rich" story about a couple who tries to find a cure for their child who has a rare medical disorder.

Amato also highlighted examples of chemistry in literature, such as the book *Uncle Tungsten* by Oliver Sacks. He said, "If there is ever a book-length love letter to chemistry, this book is it." He said there could be no better public relations coup—and something that should be done for the chemistry community and the public at large—than to turn that book into a movie. "This is where I think we should get corporate money to do this." Other books Amato highlighted included *The Periodic*

[2] *www.theodoregray.com/PeriodicTable/* (accessed November 12, 2010). Also, see B. Halford. 2007. Theodore Gray: Element enthusiast talks about making a periodic table for the 21st century. *Chemical and Engineering News* 85(48): 50.

[3] *ivanamato.blogspot.com/2009/11/gods-table.html.*

[4] Men and Molecules. 1984. *Synthesis* 7(1):43. Available at *www.roaldhoffmann.com/pn/index.php.*

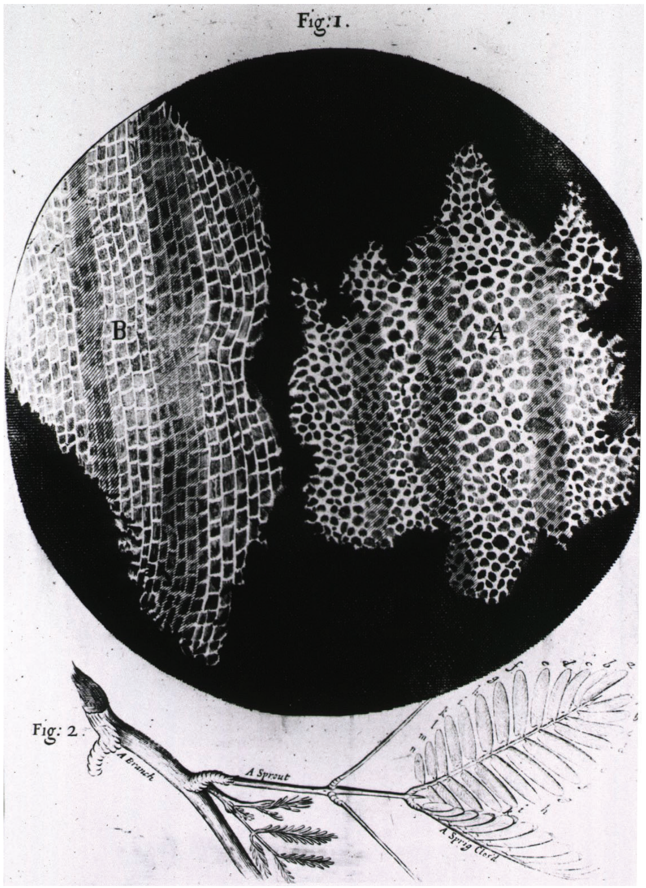


FIGURE 3-2 Engraving of a magnified view of cork tissue showing the cellular structures; a branch from a cork tree is also shown. SOURCE: Robert Hooke (1635-1703), *Micrographia*. U.S. National Library of Medicine, History of Medicine Division.

Table by Primo Levi,[5] *The Diamond Age* by Neal Stephenson,[6] and *The Sweetness of the Bottom of the Pie*, by Alan Bradley.[7]

Chemical Art

Although his main focus has been words and writing, Amato said, one of the things that has made a big impression on him is the imagery found in the primary research literature. Many of the images can be thought of as art. He said, "You can focus on the aesthetic components of it even as you think about the scientific content." He provided examples of imagery from the early days of science, including examples from early optical instruments, telescopes and microscopes. One from Robert Hooke's *Micrographia*, which he said is "one of the most important early microscope images in the history of science." For example, there is the slice of cork that Robert Hooke looked at under his microscope; he saw the compartments and thought they looked like the cells of a monastery—so he called them cells (Figure 3-2).

Other examples of impactful images Amato showed included a flea from Victorian times and the brain from a book by Thomas Willis, who was a contemporary of Isaac Newton. Another example given was the work of cellular neuroanatomist Santiago Ramón y Cajal, who won the Nobel Prize in Physiology in 1906 with Camillo Golgi "in recognition of their work on the structure of the nervous system." Cajal helped develop various silver-based other kinds of dyes that enabled him to visualize the cellular details, such as the retina neurons shown in Figure 3-3.

Amato also showed covers of *Science* and *Nature* magazines, which are magazines that "have recognized the beauty of the imagery of data forever." He thinks of the covers as "a temporally distributed walk in a science gallery." A cover from *Science* is shown in Figure 3-4. He then provided many examples of images from his book *Super Vision*. Many of the examples used scanning probe microscopies, which he described as "the Hubble instrument of chemistry if someone so chooses to embrace it that way and push it."

Amato also explained how artists are capturing images from within science labs.[8] For example, there is a photographer who collaborates with a surface scientist at the University of Georgia. This scientist works with metal oxide powders and generates structures that the photographer finds beautiful in Ansel Adams-type landscapes.

Amato discussed two more creative examples of communicating chemistry. He said that one of the best speakers he has ever heard on the Periodic Table is an artist named Rebecca Kamen.[9] She is a local Washington, D.C., area artist, who knows all about the history of the Periodic Table and generated her own sculptural interpretation of the Periodic Table (Figure 3-5), titled "Divining Nature: An Elemental Garden."[10] In an exhibition of the work, she included dancers and music to create what Amato described as an "unbelievable experience." He described how Kamen brought together "communities and populations that would never even think about chemistry or want to have anything to do with it." It was one of the most

[5] P. Levi, R. Rosenthal, and N. Ascherson. 1995. *The Periodic Table.* London: D. Campbell.

[6] N. Stephenson. 1995. *The Diamond Age: Or, a Young Lady's Illustrated Primer*. New York: Bantam Dell.

[7] C.A. Bradley. 2009. *The Sweetness at the Bottom of the Pie*. New York: Delacorte Press.

[8] One important example not discussed in the workshop is the collaborative work of Felice Frankel at Massachusetts Institute of Technology and George Whitesides at Harvard University. See F. Frankel, and G.M. Whitesides 2009. *No Small Matter: Science on the Nanoscale.* Cambridge: Harvard University Press. For more information, see *http://www.felicefrankel.com/index.html* (accessed April 13, 2011).

[9] For more information, see *www.rebeccakamen.com/* (accessed April 26, 2011).

[10] I. Amato. 2009. Rebecca Kamen: A sculptor nurtures an elemental garden. *Chemical and Engineering News*.87(40):43-43. For more information, see *http://pubs.acs.org/cen/science/87/8740sci3.html* (accessed December 26, 2010).

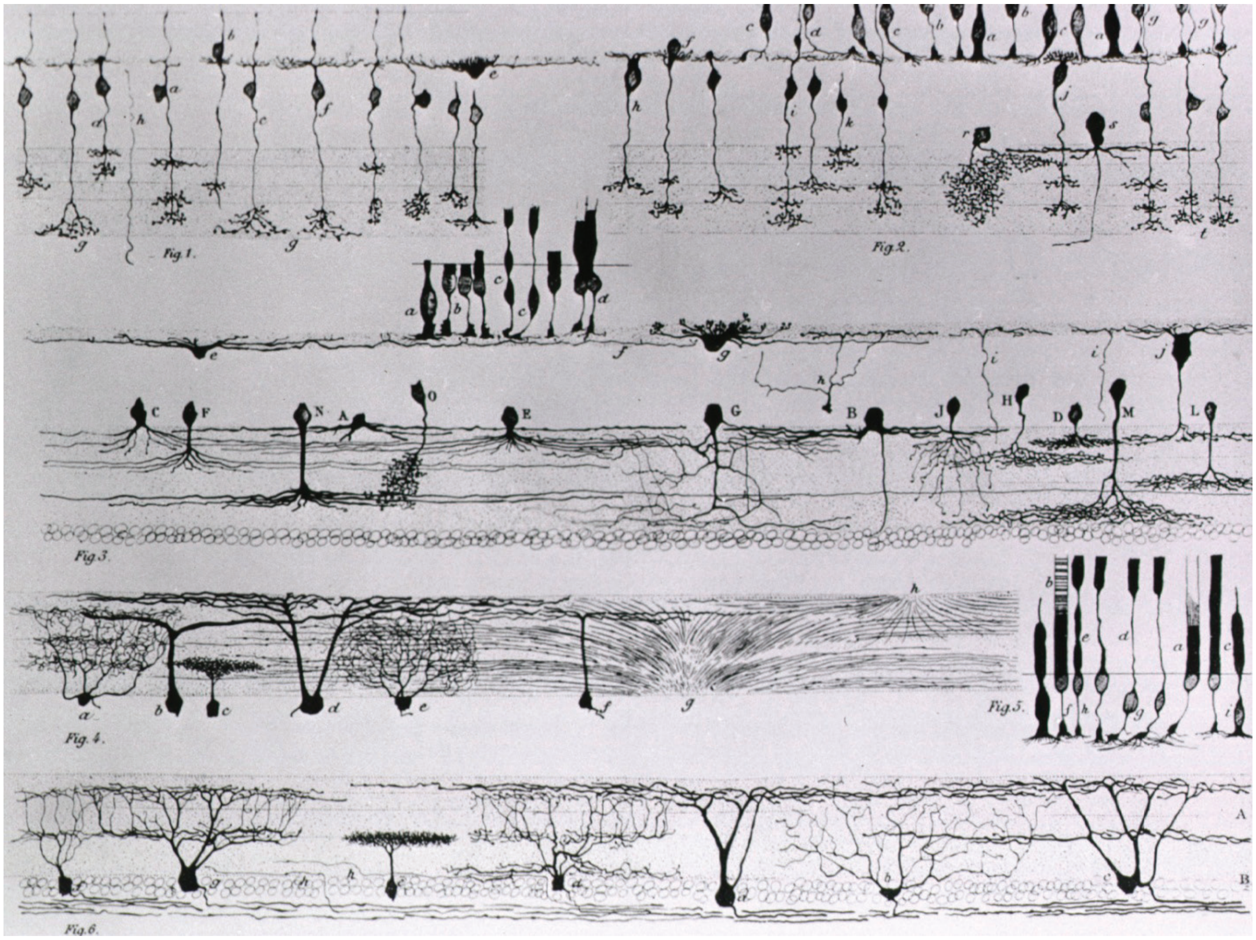


FIGURE 3-3 Various types of nerve structures in the retina by Nobel Prize winner Santiago Ramón y Cajal, based on visualization of cellular details using silver-based dyes.
SOURCE: U.S. National Library of Medicine, History of Medicine Division.

engaging presentations of the Periodic Table he said he has ever seen, rivaling that of his past chemistry professors.

Another art form Amato mentioned was theatrical plays. One example given was the play *Should've* by Roald Hoffmann, which involves the topic of synthesizing saxitoxin, one of the most toxic natural compounds known. In the play, saxitoxin is used for terrorist purposes, and this opens up interesting complex ethical discussions about how science can be used both for good and bad.[11]

FROM MAGAZINES TO BLOGS

Joy Moore talked about her company's transition from print to digital media. She explained that Seed Media Group (Seed) is a media and technology company based in New York City. It does a number of different things, from publishing a magazine to developing software. The company was funded by Adam Bligh, a young scientist who eventually founded *Seed* magazine and its parent company. She explained that Adam and the company believe very strongly in the potential of science to change the world. Therefore, the company focuses on creating media and software to support science, public understanding of science, and scientists themselves. She said that Seed uses science as a lens: "it is not the science content that is the focus, but rather science as a process and a way of thinking and a way of understanding the world around us."

Moore explained that *Seed* magazine, which has been around for a few years, recently (like many other magazines and print media) has focused more on material online. "Seedmagazine.com is really where it is at these days," she said. "We are publishing online daily, and we also publish *ScienceBlogs*, which is the largest conversation about science on the [Internet]." Moore also discussed researchblogging.com, which is

[11]For more discussion on Hoffmann's play and "Experiments of Concern," see I. Amato. 2007. Experiments of concern: Well-intentioned research, in the wrong hands, can become dangerous. *Chemical and Engineering News* 85(31):51-55.

FIGURE 3-4 Chemistry-related cover art for the journal *Science* depicts a scanning tunneling microscope (STM) image of carbon and phenolic inverse opals (image width ~17 mm).
SOURCE: A. A. Zakhidov and I. Khayrullin. 1998. *Science* 282(5390): 897.

FIGURE 3-5 A close-up of the installation, *Divining Nature: An Elemental Garden*, by sculptor Rebecca Kamen. The artist created a garden of "flowers" out of Mylar and fiberglass, inspired by the electron orbital patterns of the 83 naturally occurring elements in the Periodic Table.
SOURCE: Rebecca Kamen, Artist, Professor of Art, Northern Virginia Community College.

an aggregating service for bloggers who write about peer-reviewed research. Another feature is the Seed Visualization Lab,[12] which helps customers communicate complex data in new ways. Seed also hosts many live events, including one at the Museum of Modern Art. The event featured various scents and explained the science behind them.

In preparing for her talk, Moore looked at what *Seed* had published about chemistry. She was surprised to find there was little chemistry content, despite all of the tag words that are given to posted content. She said she asked the editorial staff about what she found, and confirmed that overall the amount of *Seed* content that has been explicitly designated as chemistry is very small. When she talked to one of her editors about why, what he told her was similar to what others had mentioned previously in the workshop. He said, "part of the reason behind the apparent dearth of chemistry content is that chemistry is easily subsumed by other fields and bigger questions, so it is about the 'why' rather than the 'how.'" For example, using chemistry to create a new clinical drug is often not reported or treated as a story about chemistry. Instead, it will be a story about health and medicine. Elucidating the processes by which carbon compounds form in interstellar space is typically not treated as a chemistry story either; it will be an astronomy-space story.

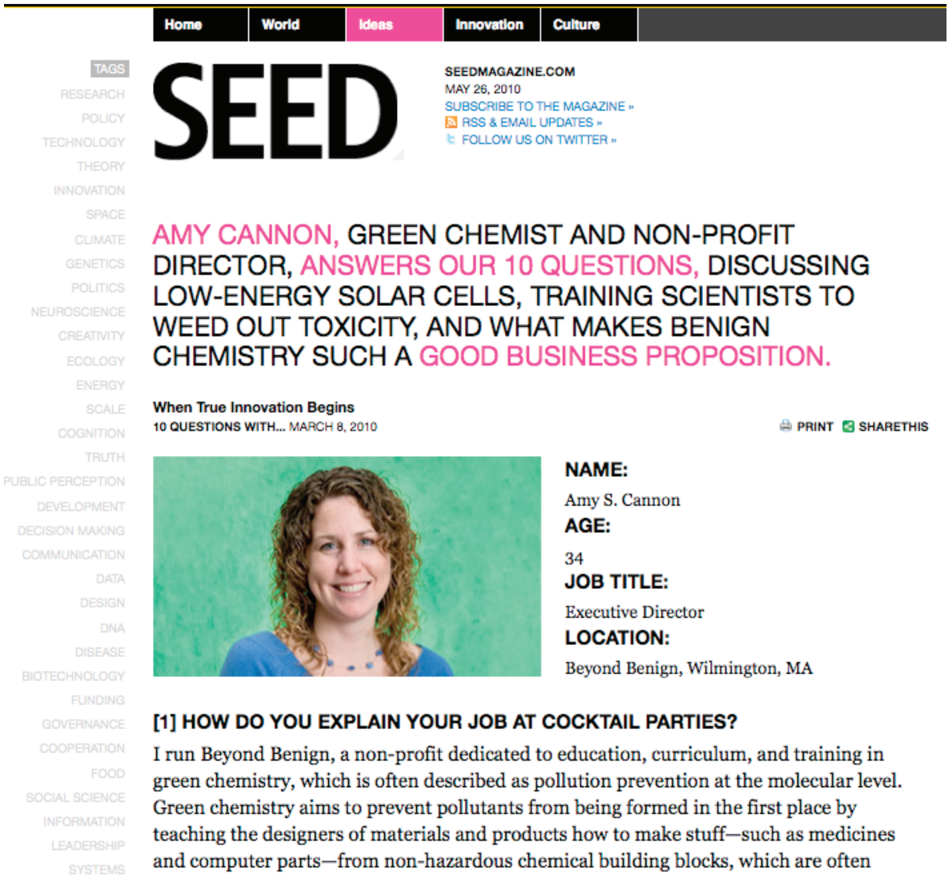
The *Seed* editor said that in his experience most pure research in chemistry is not very easy to cover or talk about in a compelling and interesting way for general audiences, for several reasons: the very long and easily confused names of many organic molecules and compounds, the frequent necessity for use of arcane and very specific nomenclature, and the tendency for most potential applications to boil down to an incremental increase in quality of a particular consumer product. Thus, from a science journalistic point of view, chemistry is a real challenge to cover, but he said, "That doesn't mean that there aren't a lot of opportunities."

A few recent articles from *Seed* specifically about chemistry were highlighted by Moore. She said there is a lot of interest in green chemistry in particular. For example, one article she showed was about green chemist Amy Cannon (Figure 3-6). Moore said that green chemistry is one area where *Seed* can intersect with human interest and the science behind it.

ScienceBlogs

Moore also talked about science blogs. She said, "I think there are a lot of really interesting things going on in the blogosphere and also a lot of potential that could help

[12]For more information, see *http://seedmediagroup.com/visualization/* (accessed April 12, 2011).



Home | World | Ideas | Innovation | Culture

TAGS
RESEARCH
POLICY
TECHNOLOGY
THEORY
INNOVATION
SPACE
CLIMATE
GENETICS
POLITICS
NEUROSCIENCE
CREATIVITY
ECOLOGY
ENERGY
SCALE
COGNITION
TRUTH
PUBLIC PERCEPTION
DEVELOPMENT
DECISION MAKING
COMMUNICATION
DATA
DESIGN
DNA
DISEASE
BIOTECHNOLOGY
FUNDING
GOVERNANCE
COOPERATION
FOOD
SOCIAL SCIENCE
INFORMATION
LEADERSHIP
SYSTEMS

SEED

SEEDMAGAZINE.COM
MAY 26, 2010
SUBSCRIBE TO THE MAGAZINE »
RSS & EMAIL UPDATES »
FOLLOW US ON TWITTER »

AMY CANNON, GREEN CHEMIST AND NON-PROFIT DIRECTOR, ANSWERS OUR 10 QUESTIONS, DISCUSSING LOW-ENERGY SOLAR CELLS, TRAINING SCIENTISTS TO WEED OUT TOXICITY, AND WHAT MAKES BENIGN CHEMISTRY SUCH A GOOD BUSINESS PROPOSITION.

When True Innovation Begins
10 QUESTIONS WITH... MARCH 8, 2010

PRINT SHARETHIS

NAME:
Amy S. Cannon
AGE:
34
JOB TITLE:
Executive Director
LOCATION:
Beyond Benign, Wilmington, MA

[1] HOW DO YOU EXPLAIN YOUR JOB AT COCKTAIL PARTIES?

I run Beyond Benign, a non-profit dedicated to education, curriculum, and training in green chemistry, which is often described as pollution prevention at the molecular level. Green chemistry aims to prevent pollutants from being formed in the first place by teaching the designers of materials and products how to make stuff—such as medicines and computer parts—from non-hazardous chemical building blocks, which are often

FIGURE 3-6 *Seed* article on green chemist Amy Cannon.
SOURCE: Web screen shot, Joy Moore, Seed Media Group.

inform the way we think about communicating in informal learning about science and chemistry." She said that Seed Media launched *ScienceBlogs* in 2006 as an experiment. The goal was to raise public engagement in science by creating a platform for conversation about science between scientists and nonscientists, she said. "Whereas *Seed* magazine's journalistic content is one way, it is didactic, *ScienceBlogs* was designed to be a forum for people to discuss science."

Seed started with 15 bloggers in 2006 and has since expanded to 130 bloggers. Moore explained that Seed picks the best bloggers, those who are going to write about interesting topics in interesting ways, and who are going to keep people coming back. They have attempted to have as much editorial diversity as possible, "We want to cover as many areas of science as we can to give the richest overall perspective." In addition, since 2006, Moore showed that *ScienceBlogs's* audience and page views have grown on a par with some of the most prestigious and oldest names in science journalism and science publishing, such as *Nature.com, Discover, New Scientist,* and *Scientific American* (based on data she compiled from compete.com performed April 28, 2010).

Seed Media had published more than 135,000 individual blog posts across the platform of bloggers, according to Moore. It has attracted more than 2 million comments, which, she said, means it is achieving its original goal of engaging the conversation, as shown by a really good ratio of comments to posts. "A lot of the excitement in reading *ScienceBlogs* is going through the comments and looking at the discussions that the commenters are having with the bloggers and then even with each other," Moore added. In addition, Seed Media has generated 300 million page views and has used *ScienceBlogs* to raise money for math and science teachers across the United States.

Moore noted that *ScienceBlogs* is giving scientists, who are also interested in writing, a platform; it gets them exposed. On *ScienceBlogs*'s website there are dozens of scientists commenting in real time on many aspects of science. She added, "Most bloggers are eloquent, funny, sarcastic, and really smart. No sooner does a paper appear in a major or even a minor journal, than they jump in with knowledgeable reactions."

Seed Media has also partnered with the mainstream media in some instances. For example, the "Science" section of the *New York Times* website shows feeds from *ScienceBlogs*. Seed Media also entered into a partnership last year with *National Geographic* digital media, where Seed provides *ScienceBlogs* content to its platforms across the world. Similar to Seedmagazine.com, Moore said there is no specific channel in *ScienceBlogs* dedicated to chemistry, but there are a number of bloggers who use chemistry in their work.

Two chemistry-related blogs were highlighted by Moore. The first one, called Speakeasy Science, is by a new blogger Deborah Bloom. Bloom is not a scientist, but chemistry informs her writing, especially her new book on the birth of forensic toxicology. Moore also showed a new public health blog from Seed, called the Pump Handle. Seed has also focused more on chemistry, in particular environmental toxins. Moore added, "So again, as we go through we can find the chemistry as the supporting characters, but maybe not the star of the show."

Research Blogging

Moore also talked about work Seed Media has done in the area of research blogging. She explained that it is not directly related to communicating science to the public, but it might provide some tools to start evaluating how chemistry information in particular is being discussed in the blogosphere. It provides some data and metrics that might help look for new ways to relate chemistry to other subject areas to get at a high profile.

Moore said that *Research Blogging* is a tagging and aggregating tool for bloggers who write about journal articles. Bloggers who occasionally discuss journal articles on their blog sites can join the Seed *Research Blogging* community. Seed provides the blogger with some code to put into blog posts that allows Seed to pick up those blog posts and aggregate them. Seed then offers the blogger on its website, Researchvolume.org. This allows people to search across the blog posts within these blogs. Moore said bloggers can also syndicate comments through the various Seed feeds, widgets, and other websites. It basically brings together blog posts about peer-reviewed research. At the same time, Seed gives a direct link back to the journal article, so that people can read the original source.

"Who are these bloggers?" Moore asked. She said the blog posts take many different forms. Sometimes someone is simply pointing out an interesting article or picking a topic and citing two or three articles to preface it. Other bloggers almost do a mini review. These are much more in-depth analyses or criticisms of papers.

Moore mentioned two researchers in the Netherlands who are studying bloggers in depth.[13] She said they focused on scientometrics and webometrics, and gathered data by going through the *Research Blogging* website. In particular, they focused on the chemistry blogs on *Research Blogging*. She said they did a completely independent analysis of how the blog's coverage of chemistry articles compared with traditional citation metrics. They concluded that the blog coverage of the chemistry literature was more efficient than the traditional citation process. The science blogs were found to be faster in terms of reporting on important articles, and they also did a better job of putting the material in context within different areas of chemistry. In general, the science blogs were also a more useful tool for navigating to new information, in contrast to waiting sometimes years for other citations to journal articles to come out.

Moored ended her talk by saying that Seed Media will continue to build on the use of new social media and the Internet to create new models for publishing as well as new techniques for reaching new audiences.

OPEN DISCUSSION 2

Pat Thiel from Iowa State University commented that many of the remarks made in this session, particularly those by Emsley, would benefit not only communications efforts geared at the scientific and general public, but also communication among scientists themselves. She said that there is too often a barrier for communication even between scientists in the same specialty, because they tend to use different languages.

Blogging and Civility

Bill Carroll asked Joy Moore about the blogs and scientific discourse. He commented, "One of the things that I find discouraging about reading many blogs or various comments is that it very quickly goes from one point of view to an opposing point of view to "you are a jerk." My question is, How do you keep [the blog] generating light and not heat?"

Moore responded that they have taken a "very, very light" editorial approach at Seed. "We leave it up to the bloggers to control their own blogs," she said. "Some of the bloggers frankly thrive on controversy. You go to their blogs because you know you are going to see a couple of fistfights, whereas others set the tone for much more civil and controlled discussions." She said that "it has been fascinating. It has been 3,

[13] P. Groth, and T. Gurney. 2010. Studying scientific discourse on the web using bibliometrics: A chemistry blogging case study. In: *Proceedings of the WebSci10: Extending the Frontiers of Society On-Line*, April 26-27, 2010, Raleigh, NC. Available online at *http://journal.webscience.org/308/* (accessed November 19, 2010).

almost 4 years, to see how this new medium has evolved. You could either try and put some rules down in order to control it, or give it some breadth to see how it evolved, and we have chosen the latter path."

John Miller with the Department of Energy asked Moore if she thinks the activity on *Research Blogging* might eventually replace the peer review system for journal articles. Moore responded that in her personal experience as a journal publisher, she definitely thinks this is a possibility on the horizon. She said, "What I find fascinating about *Research Blogging* is that a lot of these blog posts are filling the gap between the article being published today and then some months or maybe a year later when you see the letter to the editor appear in the published journal. So as thousands and thousands of people are reading these journal articles, only a few actually take the time to write up a formal letter to the editor. Then it goes to peer review, and then it may or may not be published. Because blogging is the medium that it is, we are able to see what people are spontaneously thinking and writing about right away, and that accelerates the discussions about the papers." Moore added that *Research Blogging* also improves communication from scientist to scientist, not only to the public. She said that somebody who has read the paper knows what it is about and they can digest it and explain what they think is important or what might be questionable. She said *Research Blogging* is serving the purpose of "meta-analysis of the literature, as opposed to a formal peer review."

Chemistry as the Supporting Actor, Not the Star

Steve Lyons commented that he was struck by the fact that both Ivan and Joy mentioned that one reason chemistry is not more visible is that it is often in a supporting role. Lyons asked if there was a way to get the public to recognize the critical role that chemistry plays in stories that are perceived to be about something else.

Amato said, "There is a chemistry back story, if you can have what you might call an explainer story in journalism." That is where chemistry is not the main story but it is a big part of the story. For example, in the big oil spill there is a lot of chemistry to discuss, such as the dispersants and the chemicals used in the drilling industry. He said that there are some stories like that coming out, but not many.

Another example Amato mentioned was when the "Cash for Clunkers" story came out. The killing agent for the engines was a sodium silicate solution, which is essentially "liquid glass." He ended up learning all about the sodium silicate market, how the compound is made, and what it is used for. Amato said they ran an explainer story online in *Chemical Engineering News* that was eventually picked up by the *Wall Street Journal*.

Amato also gave an example of a story he wrote about the Russian Alexander Litvinenko, who was killed by polonium poisoning. He wrote a detailed article about how polonium actually kills. *Wired* magazine later ran the story. Amato said it was a lesson on the power of social media and how stories can end up getting much, much wider exposure, "If you have the interest and it is a good topic, you can end up getting these chemistry stories out to where you wouldn't expect them."

4

Local Outreach Efforts

"Never miss an opportunity to show the human side of chemistry."
–Ruth Woodall

As noted in *Surrounded by Science*, "A first step in understanding how to promote science learning in informal environments is to develop a full picture of what it means to do and learn science. . . . In the conventional view, the lone scientist, usually male and usually white, toils in isolation to understand some aspect of the natural world through a series of controlled experiments."[1] The panel of speakers in this session, however, helped illustrate that "science is fundamentally a social enterprise" involving many kinds of people, activities, and approaches. As scientists have done for many years, these speakers engage in informal education activities in the form of community outreach. Traditionally, the outreach took the form of entertaining public demonstrations or hands-on activities with nonscientists. However, that has changed. Two American Chemical Society (ACS) member volunteers, **Jeannette Brown**, New Jersey ACS Local Section,[2] and **Ruth Woodall**, Nashville ACS Local Section,[3] talked about how they conduct outreach efforts with their local communities to put a "face on chemistry." **Catherine Conrad**, St. Mary's University, talked about a growing area of scientific outreach called "citizen science," which goes beyond fun demos and outreach activities and engages people in real scientific studies in communities throughout the world, such as the work she does with environmental monitoring and management.

NEW JERSEY ACS LOCAL SECTION

Jeannette Brown, whose background is in medicinal chemistry, explained that the ACS North Jersey section, of which she is a long-time member, participates in many outreach activities such as street fairs (Figure 4-1), 4H club activities, and special events at local museums. She noted the new ACS Chemistry Ambassador's Program, which helps to provide more support to chemists who want to do outreach activities.[4] She said National Chemistry Week (NCW), the signature outreach activity of ACS, takes place every year in late October. Her local section celebrates the event at the Liberty Science Center along with other community groups, such as the Boy Scouts and Girl Scouts (Figure 4-2). Brown noted that this year, National Lab Day was also a big event for her section. For most of the events, the ACS provides targeted educational materials that can be distributed to activity participants. Currently, she said local ACS sections are gearing up to celebrate the International Year of Chemistry in 2011.[5]

Brown stressed the importance of speaking informally about chemistry in layman's terms. She takes every opportunity, such as in a train or cab, to strike up a conversation with others about being a chemist. She said that "you don't have to dumb it down, but you have to be able to explain exactly what it is."

She highlighted a resource her local section created for teachers, a listserve (Yahoo group) called ChemEnthusiast.[6] She said that it was started by one of the chemistry teachers in their section and is now available nationwide. On the ChemEnthusiast listserve, teachers typically talk to each other about needs for supplies or other resources, but chemists (nonteachers) are also on the listserve and can respond. The

[1]National Research Council. 2010. *Surrounded by Science*. Washington, DC: National Academies Press.
[2]ACS North Jersey Section: *www.njacs.org/index.html*.
[3]ACS Nashville Section: *nashville.sites.acs.org/*.

[4]ACS Chemistry Ambassadors Program: *www.acs.org/chemistryambassadors*.
[5]For more information, see *www.chemistry2011.org* (accessed December 21, 2010).
[6]For more information, see *www.njacs.org/teacher.html#ChemEnthusiasts* (accessed November 27, 2010).

FIGURE 4-1 Student volunteers helping make crystalline models, as part of a local section outreach event during Rutgers Day, 2009.
SOURCE: Jeannette Brown, ACS North Jersey Local Section.

FIGURE 4-2 Outreach during National Chemistry Week at the Liberty Science Center.
SOURCE: Jeannette Brown, ACS North Jersey Local Section.

ChemEnthusiast listserve is also useful for posting information about events and resources.

The sections also reach out to media, such as television and newspapers. Members of the New Jersey section appeared on *Good Morning America*, and on another occasion the group invited a reporter to a local section meeting talk to gather background information. Some section members may also give community presentations and influence policy makers, as Brown has done. "In other words, we are trying to get all of our members, not just the Jeannette Browns, to become ambassadors," said Brown.

NASHVILLE ACS LOCAL SECTION

"Chemistry Ambassador" Ruth Woodall, shown in Figure 4-3, discussed the outreach efforts of the ACS Nashville Local Section. She also briefly spoke about her involvement with the Tennessee Scholars Program.[7] Woodall demonstrated an amusing example of how she connects to young people. She introduces chemistry in outreach activities and chemistry classes by using thermochromic "mood" pens; she has the students use the pens to determine who is the "hottest" to invite to the prom.

Woodall explained that such outreach efforts allow her to show a human face of chemistry. She is often recognized in different venues as the "chemistry lady" by people who have seen her give demonstrations and hand out her mood pens. She said that the local section outreach opportunities are a great way for volunteers to become engaged in the community, as well as for the community to engage in chemistry. She has enjoyed meeting people in the community and networking through her volunteer efforts with the ACS.

Woodall discussed some of the activities of the Nashville Section in her community. One example is in conjunction with a local museum, the Adventure Science Center, and involves student groups from local universities and colleges (Figure 4-4). The section also collaborates with the Nashville Earth Day in the Park each year and does outreach activities at state fairs, after-school programs, and so on.

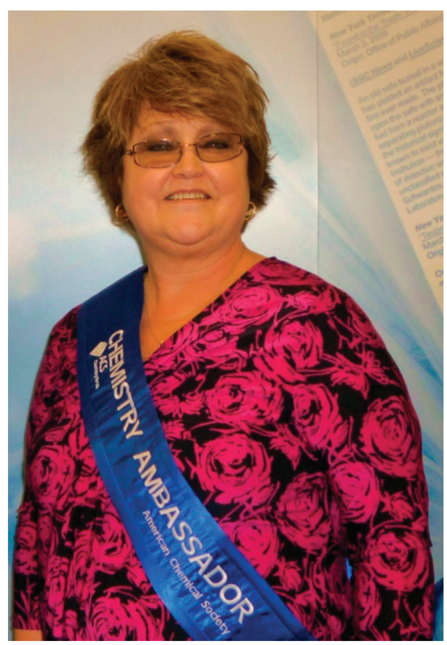


FIGURE 4-3 Chemistry Ambassador Ruth Woodall.
SOURCE: Ruth Woodall, ACS Nashville Local Section.

[7]For more information, see *www.tennesseescholars.org/* (accessed December 21, 2010).

FIGURE 4-4 Student participating in 2009 NCW event at the Nashville Adventure Science Center.
SOURCE: Ruth Woodall, ACS Nashville Local Section.

Woodall emphasized that she never misses an opportunity for outreach. For example, each year she participates in a back-to-school activity sponsored by the mayor of Nashville. He opens up the center in which the Predators hockey team plays for free to about 100 vendors to provide materials for the approximately 25,000 students that come through. She hands out pens, pencils, and Periodic Tables, as well as the activity guide for the annual NCW program. The activity guide is printed in midsummer, so it is usually available for kids at the beginning of the school year and just in time for the mayor's event.

The Nashville local section has also sponsored a variety of contests. One is the Women in Science and Engineering contest at Middle Tennessee State University. The section also conducts workshops for teachers and gives out prizes, such as the *Merck Index* to teachers at the Tennessee Science Teachers conference. She said the section typically organizes a whole day of chemistry at the conference.

In addition to the section activities, through the legislative part of the American Chemical Society, the local sections in the state have formed the Tennessee Government Affairs Committee. She explained that there is a strong bond between all of the seven local sections in Tennessee. Every year, they receive a proclamation from the governor of Tennessee for their efforts and have a picture taken with him. The group also has a significant and growing involvement in the ACS Legislative Action Network, which is an effort of ACS to get its members involved in advocacy at the state and federal levels.

The Nashville local section also has a weekly public radio program and often has articles published in local newspapers. Woodall said it is also using new media outlets such as Twitter and Facebook to increase outreach to the public.

CITIZEN SCIENCE

Catherine Conrad uses the air and water in the environment as a way of engaging people in science. She explained that citizen science is one approach to informal science education. She stressed that the volunteers she works with are people engaged in the process of gathering very credible science. They work with detailed chemical, biological, and geological scientific information.

Conrad went into detail about her work in community-based monitoring, a process in which concerned citizens, government agencies, industry, academia, community groups, and local institutions collaborate to monitor, track, and respond to environmental issues of common community concern. This type of citizen science functions on a variety of time and space scales, as shown in Figure 4-5. It is an approach that started in the ornithological program at Cornell University,[8] Conrad noted, "but one thing we are finding now in citizen science is that where it originated in the biological sciences, it is now moving into the chemical sciences. If you find that your particular favorite bird is declining, maybe there is something going on with the air quality. Maybe there is something that is going on if your favorite fish species is deteriorating or declining, maybe it has something to do with the water quality."

She explained that even though her work might be labeled "environmental," the majority of groups she works with are engaged in very hard chemical science, where they utilize quality assurance and quality control in their data collection. She stressed the high quality of the work—it is not "Mickey Mouse science."

Because of the many benefits, it is not difficult to sell citizen science to a lot of people, Conrad explained. The benefits include increased environmental democracy, scientific literacy, and social capital. "You hear about economic capital, but social capital evolves as people and neighbors and communities are working together and interacting with trained scientists," said Conrad. In addition, citizens value being included in local issues and addressing real-world problems. Their participation also enables extensive data collection.

Conrad said that scientists pay attention to citizen science because of the prospects for extensive data collection, but only "if we can guarantee that someone who is a volunteer can gather credible data using good protocols, they are trained, they have some form of certification, and the data can be upheld in an academic peer-reviewed journal." She said that many of the groups she has worked with have met or surpassed these criteria.

Because of citizen science, "We now have tentacles out in the environment that we would never have had . . . [because] not every scientist can be in everybody's pond or lake or stream or river or back yard," said Conrad. For example, she showed

[8]For more information, see *www.birds.cornell.edu/netcommunity/citsci/about* (accessed December 21, 2010).

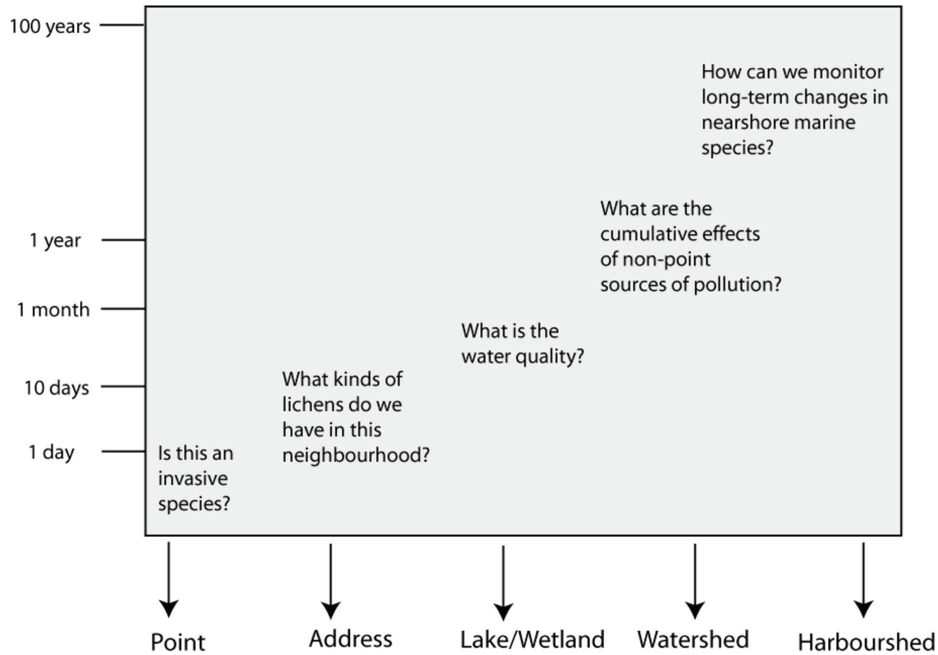


FIGURE 4-5 Citizen Science functions on a variety of temporal and spatial scales.
SOURCE: Catherine Conrad, St. Mary's University.

FIGURE 4-6 A dedicated citizen scientist collects water samples in the rain on a Friday night.
SOURCE: Catherine Conrad, St. Mary's University.

a photo of a volunteer taking a water sample at night (Figure 4-6). She explained that the water quality of the stream was so important to the volunteer that he went out on a Friday night during the summer to take a water sample in his neighborhood.

Conrad then spoke about the network she founded, the Community-Based Environmental Monitoring Network. It is housed inside the Geography Department at St. Mary's University and is a network of community environmental organizations and faculty from St. Mary's University, as well as many other universities within the Maritime in Canada. She said the network includes chemists, biologists, geologists, atmospheric scientists, green chemists, and others. She and the others in the network try to provide more than information; they "want to try and transform [information] into knowledge that people can then act upon."

Conrad highlighted the network's website.[9] She said that one of the biggest functions of the network is the equipment bank, which operates like a library system, where volunteers can sign out equipment. For example, there is the YSI 650MDS, which measures temperature, salinity, conductivity, pH, and other properties of water. Conrad noted that the equipment available is the same equipment used by the provincial government's water quality monitoring people.

In addition to loaning out the equipment, the network provides training to volunteers to use the devices. It also applies for funds to purchase and maintain the units. Conrad explained that her student Sara Weston, who was in the workshop audience, is the community-university liaison and is in charge of loaning out the equipment. Conrad noted that the group had been operating the equipment bank for 6 years and has never had a problem with equipment not being returned.

[9]For more information, see *www.envnetwork.smu.ca/* (accessed December 21, 2010).

The network has also developed protocols and training manuals for communities. In one example the network collaborated with the government of Western Australia to develop the Nova Scotia Marine Community Monitoring Manual. The group in Nova Scotia not only monitors invasive aquatic species, but is now working on ocean acidification. Local fishermen are monitoring the temperature and pH in the near coastal zone. It is very simple stuff, she said, "but they are interested in this as well, because if the ocean acidifies, that is going to influence and impact directly their livelihood—they get that." She explained that local communities are compelled to take this action, because when they go looking for answers, they often don't find the kind of information they need. There is typically no physician to tell them, as in a checkup for human health, about their local water quality or habitat conditions.

However, Conrad explained that there can also be many challenges with citizen science. She encourages people to understand the purpose of citizen science to ensure they are not monitoring simply for the sake of monitoring. Volunteers can lose interest in the work, particularly if they are not well connected with others working on the project or with the users of the data being collected. Other challenges include lack of funding, data fragmentation, lack of participant objectivity and accuracy, and lack of integration with decision makers.

Conrad started this network about a decade ago. At that time, community groups would come to her with data on slips of paper stored in shoeboxes. She did not understand why the government was not doing anything with the data. After talking with government officials, she found that the data being collected were not of interest to the government nor were they in a usable format for data analysis. Now, she said, community groups understand that they need to do a better job coordinating with different levels of government to ensure that volunteers collect the type of data the government can use—in terms of both interest and formatting.

Conrad also mentioned the relevance of citizen science and community-based water monitoring to green chemistry. She spoke to a few of her colleagues who are experts in green chemistry and learned that number 11 of the 12 principles of green chemistry[10] is real-time analysis for pollution prevention. She pointed out that the groups she works with are actively engaged in real-time water analysis.

In the last few slides of her talk, Conrad talked about efforts of the network to expand and grow. It is challenging to build the capacity and credibility of community-based water quality monitoring efforts and to develop partnerships with government to allow monitoring results to be used in decision making. To meet this challenge, the network has devised a strategy that includes developing a water certification program similar to Red Cross training courses. For example, after Red Cross training, "if you see someone who has had a heart attack on the sidewalk you could give them mouth-to-mouth resuscitation until the paramedics arrive." Similarly, non-firefighters can be trained to volunteer and fight fires; so volunteers should also be trusted and trained to do water chemistry. This program will be endorsed by the Canadian Water Resources Association. She also noted that the certification program involved the development of (1) a standardized monitoring tool-kit, (2) standardized protocols and a water quality monitoring certification course, and (3) a centralized, coordinated repository for water quality data.

According to Conrad there is significant need for high-quality products for citizen science, but existing tools have many problems, such as difficulty of use and a lack of effective manuals and explanation of basic use. For example, there are large and increasing numbers of citizen scientists involved in monitoring water quality each year, such as for World Water Monitoring Day.[11] In the United States alone, she said, more than half a million people are involved in monitoring rivers in their local areas. In addition, a poll by GlobeScan in 2009 found that 93 percent of people across 15 countries surveyed said that water pollution is the most important environmental issue to them.

Conrad ended by saying that the network is working to have maximum reach and impact by (1) establishing accuracy and consistency in the data collected by volunteers, (2) filling data gaps in watersheds and areas where existing government monitoring networks are absent, and (3) designing data collection according to government guidelines. The government especially likes it when cost savings can be demonstrated. She added, "We did a study last year [showing] that, in the province of Nova Scotia alone, we could save them 1.25 million dollars by engaging people in this, at the same time linking people with the things that they want to do in a meaningful way."

OPEN DISCUSSION 3

Beginnings

In the beginning of the discussion, panelists were asked why they first became involved in outreach efforts. Brown said, "I was always an only," always a minority. She wanted to find other African-American women chemists like herself. She also wanted to tell the world what chemistry was all about. She first volunteered to be publicity chair of her section.

Woodall said she was teaching chemistry in Memphis and was asked to come to a local section meeting as a high school chemistry teacher. She was not a member of ACS, but the section asked her to join to become the public relations (PR) chair. Eventually she became the PR chair and received training from

[10] For more information about the 12 principles of green chemistry, see P. T. Anastas and J. Warner. 1998. *Green Chemistry Theory and Practice*. Oxford: Oxford University Press.

[11] For more information, see the World Water Monitoring Day website at *www.worldwatermonitoringday.org/index.html* (accessed December 21, 2010).

the ACS. She noted that Nancy Blount, who was in attendance, taught her how to be a PR chair.

Conrad explained that her background had nothing to do with citizen science originally. She started working with a small community, and the people had more questions than she could answer. She realized that they needed a support network of people to tap into and she helped create the network. That interaction completely altered the research she was doing. She said she shifted from being an "effluvial morphologist" to doing the community-based monitoring work.

Science Cheerleader

Workshop participant Neil Gussman mentioned the citizen science effort Science Cheerleader.[12] He said the effort was created by Darlene Cavalier, a former Philadelphia 76ers' cheerleader, who is now involved with many citizen science groups.

Changes in Parent Attitudes

Mike Rogers asked the speakers how the attitudes of parents toward science have changed over time and what the activities are that interest students the most.

Woodall said that in the 19 years that she has been involved in outreach, she has noticed that more and more parents are becoming appreciative of the outreach activities the local sections offer. Parents, as well as students, are beginning to tie the outreach activities they do into the curriculum at school. "When we started, there wasn't as much chemistry being taught, and it wasn't as relevant, it wouldn't be as relevant as it is in the curriculum now. So I think over a period of time, our outreach efforts are being tied in more with the curriculum at school, and the kids are seeing more of it at school, and what we are doing is helping more in the classroom than it ever has before," Woodall added.

Rogers added that his impression is that there is a lot of interest from parents, "Even sometimes if the students aren't interested, the parents—and I think more today than they might have been in years past—there is a genuine interest there."

Woodall said she thinks that "one of the reasons that parents are becoming more interested now is because they are seeing that they are going to have to push their children into careers now even more than ever before. They see that need more than ever, and they are going to have to push their children earlier. They are getting out there and getting more active with their children."

Youth Involvement

Andrea Twiss-Brooks, University of Chicago, asked Conrad if there are youth groups or children involved in any of her community monitoring efforts. She noted that she saw mostly adults in Conrad's talk. She said she knew of groups in the United States that use youth groups and students for simpler biological or environmental monitoring.

Conrad replied that the pictures she showed did not represent all the volunteers she works with. She said that although the majority of groups she works with are typically 18 or 19 years old and older, the network does have a program working with school groups, as well as summer camps.

[12]For more information, see the Science Cheerleader website at *http://www.sciencecheerleader.com/* (accessed April 13, 2011).

5

Chemistry in Museums

"Murder and mayhem and whatnot is much more exciting than test tubes and Erlenmeyer flasks."
–Paul Bryan

Speakers in this session discussed chemistry in different types of science museums, which have served as popular venues for informal learning for many years.[1] The speakers included **Sapna Batish** from the National Academies' Marion Koshland Science Museum, in Washington, D.C.; **Susanne Rehn**, via webcast, from the Deutsches Museum, in Berlin, Germany; Shelley Geehr from the Chemical Heritage Foundation, in Philadelphia, Pennsylvania; and **Peter Yancone** from the Maryland Science Center, in Baltimore, Maryland.

CHEMISTRY AT THE KOSHLAND SCIENCE MUSEUM

Sapna Batish provided a brief history of the National Academies' Marion Koshland Science Museum (Figure 5-1). The Koshland opened in April 2004 and prides itself on being a science museum for teens, unlike many museums in the United States that are focused on an elementary school audience. All of the Koshland exhibit content is based on studies conducted by the National Research Council (NRC). An exhibit topic is chosen based on there being a major body of work by the NRC to support it, if it is continuing to be researched, and if it has significant relevance to society.

The Koshland is considered a hands-on museum. Rather than having artifacts, the museum focuses on using digital interactive equipment to convey science to its audience (Figure 5-2). The museum is also unique in that it shows the confluence of science and policy, given that its exhibits are based on NRC studies about scientific topics that are relevant to society. In addition to having a general audience, the museum also works with middle school and high school students. It offers free field trips and transportation to middle school and high school students in the Washington, D.C., area. Batish added, "We like to connect current science with tangible, real-life scenarios for students and teachers. All materials have been designed by former teachers and are field-tested with students."

FIGURE 5-1 Marion Koshland Museum, located at the corner of 6th and E Streets, N.W., Washington, D.C.
SOURCE: Marion Koshland Museum, 2010.

Koshland has three main exhibits. The first is called the Wonders of Science, which includes satellite imagery, population density, and energy use over a 10-year period, as well as the human cell. There is also an exhibit developed at Harvard Medical School featured in the museum, as well as an interactive exhibition that looks at the origins and expansions of the earth and the universe.

The second exhibit looks at emerging challenges of infectious diseases, such as malaria, AIDS, and tuberculosis, in an interactive manner. Batish explained, "In the one on tuberculosis, visitors get to be doctors. They get to choose a patient,

[1]For an excellent historical look at science museums, see A.J. Friedman. 2010. The evolution of the science museum. *Physics Today* (October): 45-51.

FIGURE 5-2 The Koshland museum focuses on using digital interactive equipment to convey science to its audience.
SOURCE: Marion Koshland Museum, 2010.

and then they administer medication to the patient over the course of 18 months, and they get to see what the viral load looks like, and they get to understand why it is that this issue is prevalent and a problem in different parts of the world."

The last of the three exhibits is on global warming. It has been there since the museum opened and displays evidence that humans are causing recent climate change. She added, "It starts off by asking, Has the climate changed, what are its causes, how might it change in the future, what are the consequences, and how can science be used to inform our responses to climate change?"

Chemistry is offered through all core areas of the Koshland, which include museum exhibits, field trips, hands-on science in the museum, community outreach efforts, public programs, and its website. As she heard many of the speakers say, Batish added, "Chemistry is just an inherent part of every aspect of life. We don't have to talk about chemistry from the perspective of an atom or a molecule at the museum. It becomes apparent to visitors that the basic fundamentals of what we are talking about are based on chemistry."

For example, there is an exhibit that shows images of ice cores. It helps visitors understand how ice cores can be used to measure the temperature of the earth 500,000 to 800,000 years ago. It involves using a ratio of oxygen isotopes from air bubbles trapped in the ice cores to infer temperature. "Then, coming back to the present, we talk about changing concentration of greenhouse gases and what that means in terms of our current and future climate," Batish added.

One of the most popular exhibits is one that focuses on decision making. The Koshland found that visitors really enjoy this exhibit because they get to consider the environmental and economic trade-offs of decisions. For example, there is one scenario in which visitors see the impact on reducing greenhouse gases when they choose between planting trees and increasing building efficiency (Figure 5-3). They get to consider the economic and environmental trade-offs of each of the options.

Based on the success of that exhibit, the museum is in the process of developing a new climate gallery. It is going to be based on two recent NRC studies—America's Energy Future and America's Climate Choices. The climate gallery will include topics such as climate science, climate impacts, mitigation, and adaptation to climate change. They will be much more focused on decision making and on advanced decision-making tools.

Batish noted that it is challenging to help the public understand something as vague and ambiguous as climate change through a hands-on science activity. She said that the

FIGURE 5-3 Consider the alternatives. Koshland Science Museum visitors make a choice between planting trees and increasing building efficiency to reducing greenhouse gases.
SOURCE: Marian Koshland Museum, 2010.

museum has been fortunate to have science and technology policy fellows (recent Ph.D. scientists) helping to develop these hands-on activities. One activity was developed by a chemistry student who was finishing up her Ph.D. in chemistry at Northwestern. It shows museum visitors how changing chemistry levels can lead to ocean acidification. The activity also helps visitors understand how ocean acidification will impact calcareous plankton, coral reefs, and other marine ecosystems.

The museum is involved in many festivals around the city. One in particular is the Arts on Foot Festival. It takes place near the Verizon Center every September. Batish showed a picture of one of the fellows engaging in an exercise that simulates the spread of infectious disease, using simple ingredients to represent bacteria, vaccines, and antibiotics. "We help them to understand how quickly disease can spread and what we can do to combat that," she explained.

The Koshland also offers public programs. Batish showed a picture of a family at a Saturday program learning about the importance of Vitamin C. It is vital for human health, and humans cannot produce it so it must be acquired it though diet. During the program, visitors test different sports drinks to determine the levels of Vitamin C. Another activity highlighted the importance of iron in fortified breakfast cereals—in its elementary form, not in combination with any other compounds. She said museum visitors were able to actually extract iron from a slurry of breakfast cereal flakes in a Ziploc bag using a strong magnet.

Finally, Batish noted that there are DVD ROMs and interactive exhibits on the Koshland website that help people understand the importance of chemistry and its relevance in today's society. One example is Safe Drinking Water Is Essential. It is a virtual (online) exhibition on safe drinking water. She said that the online exhibition attracts domestic as well as international audiences. It also attracts decision makers, nongovernmental organizations (NGOs), and educators and is available in five languages. "What we really want people to understand is, it demonstrates the evidence for the growing populations without access to adequate drinking water. It gives survey solutions and technologies to increase the quality and quantity of drinkable water in the world," Batish concluded.

CHEMISTRY AT THE DEUTSCHES MUSEUM

The next speaker provided insights from a museum known internationally for its exemplary chemistry and chemical engineering exhibits, the Deutsches Museum (Figure 5-4). Susanne Rehn explained that the museum is the largest science and technology museum in Germany, with approximately 1.4 million visitors annually. It was founded by Oskar von Miller in 1903. She mentioned that since the beginning of the exhibitions, there has always been a chemistry department.

FIGURE 5-4 The Deutsches Museum, which opened its doors on the Museum Island in 1925, is the largest science and technology museum in Germany, with approximately 1.4 million visitors annually. The chemistry galleries with approximately 1,000 square meters have been closed for redesign since 2009.
SOURCE Susanne Rehn; copyright: Deutsches Museum.

The original chemistry exhibition was divided into two sections, one historical and one focused on modern applications of chemistry. In parallel there were exhibitions of chemical engineering. She said chemistry now occupies about 1,000 square meters, roughly 10,700 square feet, on the first floor of the museum building. However, the museum's chemistry exhibition has been closed to the public since autumn 2009. It will be completely redesigned, with an expected opening in 2012. The three historical laboratories, replicas of the alchemy laboratory, Lavoisier's laboratory (Figure 5-5), and Liebig's laboratory, are very popular and will continue to be a part of the renovated exhibition.

Rehn said, "The laboratories were designed according to historical models, putting visitors into the appropriate time. Essentially the visitors become part of a life-sized stage. The stage shows and explains basic methods and insights gained during the time, but individual objects, chemistry explanations, and persons take a back seat." The alchemy laboratory represents a typical post-medieval laboratory based on paintings of David Teniers the Younger.[2] From the beginning, she said, the laboratory replicas were meant to show the abundance and variety of equipment and materials used in the past. Over the decades, they have had to reduce the diversity, and install a railing and an alarm system.

Rehn then talked about the old exhibition of scientific chemistry. Visitors entered the exhibit after the historical laboratories. It featured a high standard with regard to con-

[2]To view historic artwork depicting alchemy, see the Chemical Heritage Foundation website at *www.chemheritage.org/discover/collections/search.aspx?collectiontype=Fine Art&q=alchemy* (accessed November 29, 2010).

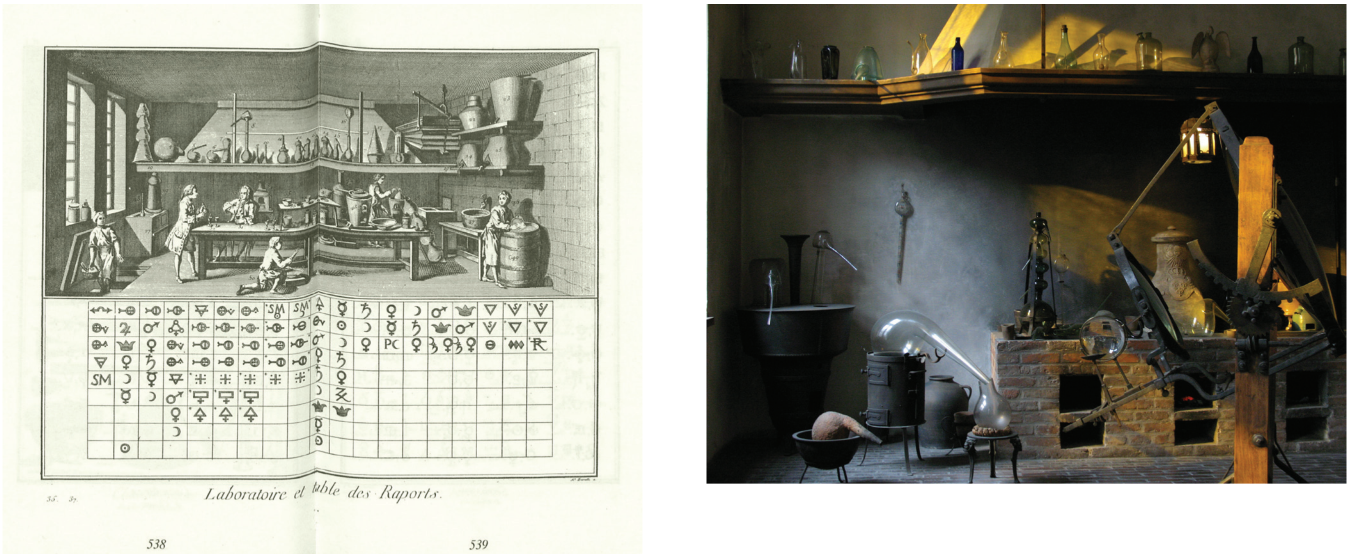


FIGURE 5-5 The chemistry galleries in the Deutsches Museum are famous for their life-size reconstruction of historical chemical laboratories. A typical laboratory of the eighteenth century was built after an illustration found in Diderot's *Encyclopedia* (left). Being the same period in which the great chemist Antoine Laurent Lavoisier lived, the laboratory is called "Lavoisier's laboratory" (right). Other historical laboratories in the museum show chemistry in medieval times and in the nineteenth century.
SOURCE: Susanne Rehn; copyright: Deutsches Museum.

tent. There were different chemical reactions set up behind glass that could be performed with the push of a button. The reactions demonstrated chemical foundations, such as acid-base reactions, coordination complex reactions, redox reactions, and so on. However, no connection was made between the reactions and the daily lives of visitors. The design was also quite monotonous, with long corridors that left the public uninspired and unengaged in the information, according to Rehn.

The exhibition did contain occasional historical objects. For example, it included the famous table showing the original instrument used by Otto Hahn and Lisa Meitner when they discovered nuclear fission. In contrast to the historical laboratories, the objects found near the chemical reactions were described in detail.

Rehn explained that the previous exhibition had some great merit because it focused on chemical experiments. Visitors were able to conduct a large number of experiments, which they enjoyed. The experimental equipment was simple, but it was not visible to the visitor, which made it difficult to understand the science going on. Also the glass window between the experiment and the visitor created a distance that kept people from reading the text and understanding what happened.

The third feature of the chemistry exhibition, even more popular than the historical laboratories and chemistry experiments, was the experimental lecture. The lectures took place up to three times a day and attracted an audience of about 14,000 during the last year the exhibition was still open.

Rehn said, "One can speculate about the reasons for this popularity. One reason may be that the [lecture] experiments shown resulted in spectacular displays. Another may be that the background to each reaction was explained on the spot by the colleagues holding the lectures. Personally, I believe that a significant reason can be found in the lack of distance. No glass between the visitors and the experiments, no long texts to read, and so on." In approaching the redesign of the chemistry exhibition, the museum had as its goal to expand upon the basic approach of turning chemistry into an experience. It wants to show that chemistry is an innovative, responsible science. "I don't know how this is seen in the United States, but in Germany there is considerable prejudice against chemistry, regardless of any achievements of the past. Chemistry may be any of these: unnatural, toxic, harmful. On top of this, chemistry only happens in laboratories far, far away. Our goal is to break up this rigid image and consciously highlight chemistry where visitors meet it every day," explained Rehn.

"One of our most important messages is that chemistry has benefits for every one of us in the whole society," Rehn said, so the selected topics include sports, fashion, leisure, and so forth, which explain plastics and advanced materials. Other topics include nutrition, cosmetics, construction, and energy stores. A section called analytics will feature forensics. "We are designing a virtual crime scene, and visitors will be able to find out more about the scientific background of analyzing each piece of evidence. This way, we lead the visitors through analytical principles like paper

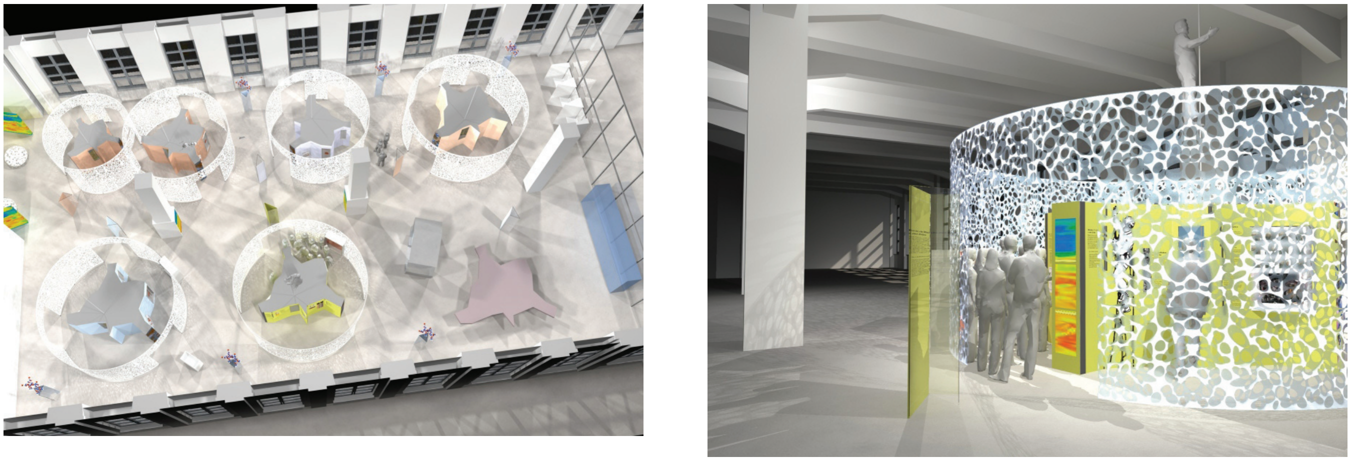


FIGURE 5-6 The complete redesign of the chemistry exhibition. The approach is to turn chemistry into an experience. The museum wants to show that chemistry is an innovative, responsible science, which happens every day around everybody. The selected topics may include sports, fashion, leisure, nutrition, or industrial raw materials. There will also be a hands-on laboratory, as well as a modern lecture room for 100 visitors to complete a visitor's interactive experience.
SOURCE: Reprinted with permission of Ambos & Weidenhammer and the Deutsches Museum, Munich.

chromatography," Rehn explained. She said that part of the new exhibit will also allow visitors to experience learning about basic chemical principles such as acid-base reactions, and so on.

Rehn showed some drawings of how they think the new exhibition will look. Topics will be shown in what they call islands, without a shell or membrane (Figure 5-6). The interior of each island will hold a core element of the exhibition, as well as text, graphics, original objects, and demonstrations. She said that the challenge for chemistry will be showing something that is really too small to be seen: "Unlike an airplane or a combustion engine, I cannot put molecules on display in a glass case." They will try to show everyday products that receive their special properties thanks to chemistry. Also, there will be both historical and modern objects, such as analytical instruments, laboratory equipment, and materials samples. Rehn showed a sketch from a demonstration of hydrogen bonds, where visitors can move one water molecule with a handle on it, and as they do so they can see how the intermolecular forces act on the other water molecules around it, and how they rearrange themselves accordingly. Future visitors will be able to do chemistry experiments in a hands-on laboratory and again take part in lectures in the auditorium.

Rehn finally showed drawings of the auditorium and laboratory complex in the new exhibition. She explained that the exhibits will be located in such a way that the visitors will walk along a time line showing the laboratories from the sixteenth century up to today. "While visitors will be able to see the historical laboratories like three-dimensional paintings, they will be able to walk into the hands-on laboratory and run their own experiments," Rehn added.

THE MUSEUM AT THE CHEMICAL HERITAGE FOUNDATION

The next speaker highlighted a museum completely dedicated to chemistry. Shelley Geehr described the Chemical Heritage Foundation (CHF) as a library, a museum, and a center for scholars. She said, "We like to say that we tell the story of chemistry, we don't do chemistry." Through its museum and public program, CHF fosters an understanding of chemistry's impact on society—through its collection, research, and fellowships. Geehr explained that the museum is the newest part of CHF, having just opened in 2008. For a long time, she said, CHF was a library and a center for scholars. "We did a lot of collecting of materials, the papers of scientists, their old instruments, artwork, objects, artifacts, things that told the story of chemistry through time. We came to a point where we realized that there was a need and an interest in making these items more accessible, not just accessible to our scholars and our researchers, but to a broader public," said Geehr.

CHF is located adjacent to Independence National Historical Park, which has helped attract visitors to the museum. Geehr said they take advantage of the fact that Independence Historical Park has more than a million visitors a year, and many of them go by CHF and end up going in. The CHF museum had about 15,000 visitors in its first year of operation, with almost half of them from outside the Philadelphia area. At the same time, CHF is not open on weekends, which significantly affects museum attendance.

The main exhibition CHF has is called Making Modernity. It is a permanent exhibition and has a range of interesting items: fine art, laboratory equipment, rare books, and everyday objects. The items are from the 1600s to the present. The aim of the exhibit is to show how chemistry touches everyday life. Geehr said: "I think you have heard that over and over again this afternoon. That is what really works—to show people where chemistry exists in their everyday life." As an example, she mentioned computers and how making a computer chip is a chemical process.

CHF exhibits cover a range of topics, from alchemy, to synthetics, to the chemical instrument revolution. She showed some cartoons poking fun at scientists and other chemical artwork. She noted that CHF has one of the largest collections of alchemical paintings in the world, and these paintings are a wonderful way to show people how science has been a part of our lives. She added, "Investigation has always been a part of our life, and it used to be done within the home, [we] show people that this is very much a human endeavor. That is our strength, to show how these things fit in context, to show through art, through objects, rather than through the individual experiments or the hands-on discoveries."

One example of an interesting everyday object Geehr showed was a wedding gown made out of an Army surplus nylon parachute (Figure 5-7) from World War II. She thought it was a wonderful story to tell, how after the war "people used fabrics that were designed for other purposes and were able to change them and transform them."

CHF also does public programming. There are tours and themed talks, as well as informal lectures. The goal of these programs is to provide the public with more tools to understand contemporary issues, to appreciate the role of chemical sciences in everyday life, and also to provide people in the field—the science and technology professionals—with a broader perspective. The museum is aimed at the high school and higher level, and scheduled tours are offered to high school and college groups, as well as to business groups visiting the conference center. Staff have developed three tours with a task force of practicing teachers and a couple of education consultants, called Chemistry in the Public Eye, Elements of Knowledge, and Creative Chemistry, each of which provides a different-themed way to go through the museum exhibition. They also customize tours as needed.

FIGURE 5-7 Everyday objects. A wedding gown made out of an Army surplus nylon parachute from World War II.
SOURCE: Shelley Geehr, Chemical Heritage Foundation permanent collection.

Another activity Geehr mentioned is participation in a science café[3] CHF started called Science on Tap, in collaboration with four other Philadelphia science institutions: the Academy of Natural Sciences, the American Philosophical Society Museum, the Wagner Free Institute of Science, and the Mutter Museum of the College of Physicians. She said that it is an inexpensive and amazingly successful program. The café takes place the second Monday of every month, with each group taking turns to bring in a speaker. The format includes a very brief lecture followed by an extensive Q&A in a bar. She said it has been "wildly successful." The first one had 50 people, and they have never had less since then, "even during the Philly playoffs!" said Geehr.

Another successful activity is CHF's First Friday program. CHF is located in Old City Philadelphia, and many art galleries in that area stay open late on the first Friday of every month. There are many people around at that time, strolling around, looking at art, getting something to eat, and having drinks. CHF stays open late too and offers activities to attract visitors to the museum. Activities include making molecular origami, batteries out of lemons, and sun prints. Gehr noted, "It is amazing, the number of young people and adults who come in. They sit down, they will work on a small project for 20 to 30 minutes, and while they are doing this, we have someone walking around in a very casual way, talking about the science or the chemistry of what they are doing." She said that last December they made papier maché ornaments and had a staff member who is a chemist talk about starch chemistry. People had to leave the ornaments behind because they were too wet, but they came back the following Monday to get them. "So it tells you that they had a good time, they valued it," said Geehr.

In addition to the museum and activities, CHF also has a magazine, which Geehr described as its touchstone. "It has been around since the beginning. We use it to tell a variety of stories about the history of chemistry. We get tons of letters, tons of people coming up to us saying we love your magazine, particularly teachers. A lot of teachers find ways to use these features in their classroom." The magazine staff also works closely with CHF web staff to expand the communication of

[3]There are many science cafés in place across the county. For more information, see *http://www.sciencecafes.org/* (accessed April 13, 2010).

content. The magazine only comes out three times a year, but staff would like to move more of the content to the web.

CHF has additional features on the web, such as its weekly podcast called Distillations.[4] Geehr said that CHF has been producing the award-winning Distillations program since 2007 (the New York Festivals gave CHF three bronze medals for the podcasts in 2009). CHF also has three blogs, which she said all have very distinct voices. One is for the CHF scholarly community; one is the CHF president's blog, where he talks about a variety of topics that interest him; and the third is called "The Center," which highlights research and other activities by scholars in the CHF Center for Contemporary History and Policy.

Gehr noted that CHF is also getting involved in social media, such as Facebook, Flickr, Twitter, and YouTube. She said that Flickr has been particularly valuable for CHF, because the images get picked up and used in various places. "Jezebel, which is a feminist blog, picked up an image of our chemistry set for girls, a beautiful chemistry set in a pink box. It is actually called a lab technician's set for girls," Geehr added. She said that there were more than 100 comments on the image. In another example, *Wired Science* picked up a CHF image of litmus paper. "We have had successes like that, a way to get our collections out in the world and get people to talk about them," she said.

Geehr ended with an image of CHF's anniversary cake, on the first anniversary of its museum. It was a Periodic Table of Cupcakes (Figure 5-8), which was featured on a blog as well. She said there were two young women, who just started an AP chemistry course in their high school, who planned to get H and I—hydrogen and iodine—spell HI, and then eat their cupcakes. Geehr reported that "unfortunately they got there a little too late so they couldn't do that. But there was such enthusiasm to do something like that. They made their mother drive them in from the suburbs and they were just lovely."

She said, "I think there is a great deal of hope going forward. I think telling the stories, the people, the innovations, the way it affects our lives each and every day, I think that is the way to truly draw people in, and show them beautiful things, show them artwork, show them Bakelite buttons, and they get it."

The final speaker on chemistry in museums was Pete Yancone, from the Maryland Science Center. "If you visit Maryland Science Center you won't find any [chemistry-specific content], at least nothing labeled Hall of Chemistry," said Yancone, but he explained how the museum provides chemistry content and experiences in a variety of ways. He described the Maryland Science Center as a typical science center. He said it was recently renovated, but chemistry is not one of the core group of exhibits. He said, "That makes it more incumbent on my staff to recognize the opportunity for chemistry and to extract it from those kinds of experiences that we do have and that do come through the museum."

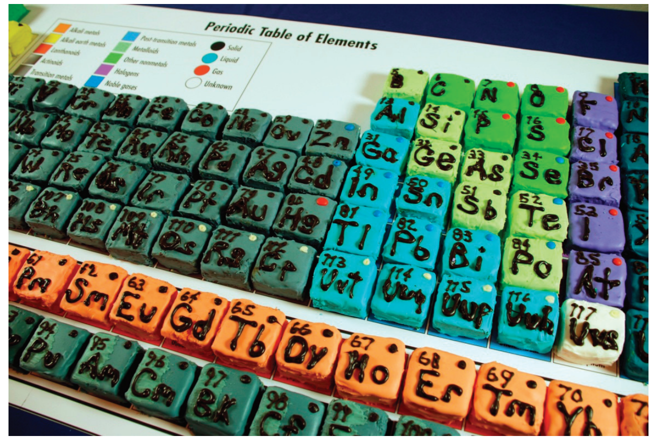


FIGURE 5-8 Periodic Table of Cupcakes. An arrangement of cupcakes in the form of a Periodic Table of the Elements was created to celebrate the first anniversary of the opening of the Chemical Heritage Foundation Museum. People in the lobby could not wait to get into the room to have their cupcake on a Friday night in October.
SOURCE: Shelley Geehr, Chemical Heritage Foundation.

Yancone elaborated on some of the more practical aspects of trying to implement large-scale chemistry exhibits and demonstrations in museums and what prevents some museums from doing more. He noted that it is not trivial to incorporate chemistry into a museum. Yancone said, "This is not the kind of thing that says, if only we had a little more energy or I had one more staff person, I could overcome all this and, presto, I would have a chemistry exhibit. Safety is a paramount thing. On the one hand you are trying to create a sense of ease around chemistry, but you also have to keep the fire extinguisher at hand. You also have to make sure that the materials that you have designed the exhibit with are going to withstand it."

Yancone explained that staffing is a critical issue, because staff need to be comfortable with the activities, otherwise any uneasiness they have will register very quickly with the audience. Sometimes staff require special training to handle chemicals. The museum typically doesn't have a staff chemist; there are volunteers, however, who have worked in the field or who have taken some course work. Finding or hiring a chemist is not always possible.

Chemistry exhibits are also expensive, said Yancone. "It is not like some exhibits where you can build it and 5 years later you have spent nothing more than changing the light bulbs on it and maybe sending the cleaning crew through. If you are doing chemistry, you have got to keep the chemistry coming," he added. This can be the deciding factor for museums to create a chemistry exhibit versus one on physics or other topics.

Yancone also pointed out, "Good chemistry, exciting chemistry is messy chemistry." He said that this affects safety

[4]For more information, see the Chemical Heritage Foundation Distillations website at *www.chemheritage.org/community/distillations/index.aspx* (accessed November 30, 2010).

and the facility itself. Disposal of used chemicals is a major concern, particularly for outreach and travel to schools. "What do you do with this stuff? You are left with one collection of chemicals that now becomes something else. Can you leave them at the school? Maybe not. You bring them back, and then what do you do with them?" Yancone added.

On a positive note, Yancone said that chemistry is very popular: "every survey we do of our visitors, they want to do chemistry. Their sense of the chemistry that they want to do is not electron dot diagrams. They don't want to come in and calculate the probability of electron orbits. They want to mix stuff together and see what happens."

In terms of exhibits, Yancone pointed out that there is a big difference between interactive and static displays, and there is a reason to have both in a museum. They have tried interactive chemistry exhibits with mixed results. They had an acid-base titration, where the reagents were metered out with the push of a button. It only lasted for about a week. The plan had called for the exhibit to be filled about once a day with reactants, but once it was opened to visitors, 5 liters of the chemicals disappeared in less than an hour. Five milliliters of reactant was metered out every press of the button. Yancone lamented, "It turns out it was really motivating for visitors to press that lever and get 5 milliliters of stuff, and like rats in a cage, they were pressing away, because if 5 milliliters works, 10 milliliters must be at least twice as good."

Yancone noted the special importance of demonstrations in a museum. He said, "It is part of a noble tradition." He said that many people will remember even a decent display of chemical phenomena, whether it is a university celebrating Chem Day, the college fair, a science museum, or the World's Fair. He recalled seeing DuPont's Wonderful World of Chemistry at the '64 World's Fair. He said, "I had forgotten all about it until one day on our demonstration stage I realized I was doing that demo and was surprised to remember it in that context." Yancone noted, however, that demonstrations are for the most part passive. Sometimes visitors may be included, but this is always a judgment call. "One of the concerns that we have is whether a volunteer adds something to the presentation or not," said Yancone. He said the best thing about demonstrations is the spectacle. He said it is the kind of thing that works really well for promotional purposes.

Yancone said that IMAX has now reached into the chemical arena with programs such as the Molecularium show.[5] He said that the planetarium could also become a place where you can display medium crystal lattices. He also mentioned the topic of facilitated lab experiences, such as the cell biology experiments that Kirsten Ellenbogen discussed. Maryland Science Center also received a Dreyfus grant to provide similar activities, which included biochemical and inorganic chemical experiences.

The challenge in those spaces, Yancone said, is to make them meaningful. "As a visitor, you walk in, you sit down, the staff provides you with materials, or you sit at a bench that is already pre-stocked. It is really fancy. You get to put on a white coat before you sit down, and maybe you glove up and you wear the safety glasses." The experience is ideally an investigation, but sometimes it is just cookbook chemistry. The visitor follows a procedure with computer guidance, and everything works. However, he said, occasionally the computer or the program text will lead the visitor through branching, and there are choices to make and predictions to make. "Then you are actually doing an investigation," said Yancone, and "visitors really like this stuff. They are doing it hands on. Even when it doesn't work for them, they are really happy that they had the experience."

Another aspect of the museum is conducting classes and workshops. Yancone described how the classes and workshops often help supplement the exhibits. For example, he discussed a new exhibit coming to the museum on marine archeology and shipwrecks. He said that part of the experience is about conservation of objects removed from the bottom of the ocean, which is a great opportunity to do electrochemistry. "When you don't have a chemistry exhibit, this is where you put your chemistry," said Yancone. The big challenge though with classes or experiences for school groups, drop-in weekends for visitors, especially families, Yancone said, is that "you have got somebody who is middle aged walking in with a teenager, walking in with a 5-year-old. The experience has to work for all of them." He noted that they also offer an overnight camping program and after-school and homeschooler programs. "All of those are out-of-school kinds of experiences. There the audience is school age children, but they are not in their school mode and that makes them operate differently," he added.

Another challenge of conducting chemistry activities, Yancone said, is "there is always a dynamic tension between education and marketing." He said that it is easy for the marketing staff to declare that every chemical experience is somehow chemical magic. However, many visitors cannot tell the difference between magic and chemistry, so while the education department undersells the magic piece, "the marketing department always stuffs that in," he added.

Yancone also talked about the museum's involvement in promotional events. "Things that are event based certainly garner media attention. Where does the local TV outlet turn when it wants to hear about, I don't know, the fact that air quality has been down over the city for the past week because of some temperature inversion. They can't interview their own meteorological staff, so they have to talk to somebody and, fine, come to the science center. When National Chemistry Week (NCW) takes place, especially on the weekday, where are you going to go to find an audience? It is October. The museum would be a good place to try," he explained.

A topic that hadn't been discussed much by other speakers is the role of the museum store. "Much like our surveys of visi-

[5]IMAX Molecularium: Molecules to the Max, *www.moleculestothemax.com/* (accessed November 30, 2010).

tors that say they all want to do chemistry," Yancone said, "it turns out that the science store at the Maryland Science Center, when they ranked what they sell, dinosaurs is number one, right behind it is anything related to chemistry." Even though there is not a strong presence of chemistry in the museum, it is what people are walking out of the store with. Space comes after that. He mentioned that at one time there were some science stores at museums that turned into a local resource for labware and reagents, but this didn't last long due to liability and security issues.

Yancone concluded by talking about how the museum uses the Internet. The museum website provides extensions to exhibits and activities. In the case of chemistry, he said, all of the chemistry demos have activities that can be done at home. For example, when the double blizzard hit the East Coast last year, the museum found that the hits on its website were those take-home activities.

OPEN DISCUSSION 4

Note: *This session covers topics introduced by speakers and participants in the immediate and preceding workshop sessions.*

Bill Carroll pointed out that about 20 years ago, the DuPont slogan was "Better Living through Chemistry," showing how its business was connected to the experience and quality of life. He said that a lot of what had been discussed during the afternoon session focused on the relevance of chemistry to everyday life. However, now the DuPont slogan is Miracles of Science, Carroll pointed out. He then posed the question to workshop participants, "Do we still have the sense of the miraculous; do we still have the gee-whiz factor for the kinds of audiences that you are attracting to your programs? Or is some of that getting lost behind a greater emphasis on relevance?"

Yancone responded that some of that "gee whiz" factor has been lost. He said, "There was a time when people lived closer to real life, not so much a virtual experience. I think about my neighborhood. Five years ago I could see kids riding bikes and playing outside. Now they are all inside playing videogames where they are riding bikes and playing sports online. If you looked under your kitchen sink, you found ammonia and vinegar and Drano, and Drano was labeled as lye. Now there are cleaning products that have fancy names and fancy packaging, but nobody knows what is inside the containers, and they all have Mr. Yuck stickers on them and you are not supposed to get near them."

On the one hand, he said he sees young people impressed by things that he wouldn't have considered so impressive, because they have not seen the phenomenon before. For example, he said "If you bring 8-year-olds in and develop a print in black and white with some chemistry, they are in awe. They can operate a digital camera, they can process the image, they can give you 10 ways to print it, but seeing the chemical process that produced the black and white image, I guess I am still impressed with that myself, but not the way they react to it."

Geehr believes that understanding how relevant something is, is a "gee-whiz" moment for a lot of people. "If you look at some of the younger people, they have never lived in a world without plastic. They don't understand that there used to be a time when these things were difficult or complicated." She said that one of the things they have in the CHF museum, which is a little shocking to people are tools that physicians use for diphtheria. As the throat closed, these stainless steel devices were shoved down the throat to open it and prevent people from suffocating.

No Chemical Formulas, Ever

A participant asked Geehr about the use of chemical formulas and molecular structures in the CHF museum: "How important do you think [structures are] as a mediator in public understanding of what chemistry is all about?"

Geehr responded that as a history museum, CHF has concentrated on telling the story and explaining it, but not really showing the chemistry explicitly. "So that is our out, that we are a history place, so we don't have to do the little chemical diagrams." However, she said that they do use them when it's important. "We explain them, but occasionally you have to show that this molecule comes together with this molecule," she said. For example, CHF has a temporary exhibit right now, which includes a computer program that allows visitors to build Viagra. She said that people spend a lot of time on it, "so you can do it, but you have to put it in context." She also added, "It is a sad thing to say, but since the exhibition is about society's reactions to chemical innovation and a lot of those reactions are to make fun of [it], we went with Viagra because it makes people laugh. You could have done it with anything, but Viagra makes people laugh."

Batish agreed with Geehr. She said, at the Koshland they focus on how science is relevant to people in their daily lives, which includes chemistry at all different levels. However, it is not always necessary to show or work with chemical molecules.

Rehn commented that in the new exhibition at the Deutsches Museum, they want to make people curious about the chemical background of everyday stuff. They show visitors everyday items, and then the visitor is supposed to ask, "What does this have to do with chemistry?" Then they show the visitor the molecules and the formula, so they know it is not a secret science as in the time of alchemists.

Celebrating International Year of Chemistry

Nancy Blount, American Chemical Society, asked the panelists if any of them have anything particular planned around the International Year of Chemistry in 2011 (IYC 2011) or, if not, could they suggest what they might do to bring this to the attention of their visitors. Also she asked them to suggest opportunities for collaboration.

Batish said collaboration is very important. "I think that would be an excellent way to bring different groups together. We would be more than happy to share our experiments with you, if you are planning to have anything in a different venue, a different city," she added.

Rehn said they tried to open the new chemistry exhibition for IYC 2011, but it wasn't possible, "so we are very sad about that." They may have little activities showing chemistry in the yard of the museum or special lectures, but this is still uncertain.

Geehr said that the Chemical Heritage Foundation is very excited about the International Year of Chemistry. CHF is working with the American Chemical Society (ACS), the American Institute of Chemical Engineers (AIChE), the American Chemistry Council (ACC), and a number of groups within Philadelphia to launch the International Year of Chemistry here in the United States. A series of activities is scheduled for the first week of February, after the international launch in Paris. Also, CHF is working with a number of groups within Philadelphia to insert chemistry into unrelated events, such as the International Festival of Fine Arts. It is hoping to bring the Madame Curie interpreter in to perform.

Open Chemistry Labs

Rosenberg wanted to know more about how the Deutsches Museum plans to administer an open lab. He noted how the old chemistry exhibits were great, but they were behind glass as she said, and now the museum is trying to bring them out from behind the glass. He said he went to a museum in Switzerland, Technorama, where they had a totally interactive exhibit, but with no real guidance. "You could go up, put your hand in a glove box and play with liquid nitrogen and smash things. At the same time, there are examples such as at the museum in Maryland, where the kids pressed the button so much that the exhibit had to be taken out."

Rehn said that in Germany, there are many labs with open plans, such as at the company Bayer. She said lots of universities do similar things—they have a laboratory, a basic set of reactions, most of the time including household chemicals such as ammonia, vinegar, lemon juice, or something similar. There is also a set of recipes. She said that fortunately they will have museum staff and Ph.D. students through a collaboration with the University of Munich Chemistry Department. The students will be involved in creating the classes, giving support, and evaluating the classes. She said, "I hope we can manage it, both personally and financially."

Jeannette Brown noted that the CD-ROM the Koshland created on water will be great for the International Year of Chemistry. She also suggested that the CHF look into the National Science Foundation (NSF) History Makers program,[6] about inspiring African Americans, which includes numerous oral histories of African-American scientists (saved digitally). She said it would be an excellent resource for involving African Americans during IYC 2011. She also mentioned the collaboration between CHF and the National Organization for the Advancement of Black Chemists and Chemical Engineers (NOBCChE). Geehr also noted CHF's collaboration with the African-American Museum in Philadelphia. She mentioned that they may bring Steve Lyon's Percy Julian film back to the African-American Museum to launch Black History Month with a chemical theme.

Brown also recommended that all museums consider doing activities on the science of color. She said that she has a video and other materials about how Native Americans used natural plants to obtain dyes for textiles: "So a lot of this stuff can be done. It is all out there, you just need to organize it and show it."

Chemistry in Prime Time

Ruth Woodall changed the subject to chemistry in TV and the movies. She mentioned that the 2010 theme for NCW is about chemistry in the movies: "Behind the Scenes with Chemistry!"[7] She encouraged everybody to go to the website Chemistry.org/NCW and provide feedback. She also encouraged participants to go their local areas and help celebrate National Chemistry Week.

Bill Carroll brought up the popularity of the TV show *CSI* (Crime Scene Investigation). He said that he has talked to a lot of high school students and has asked them what made them think about studying forensic science and chemistry, and the answer usually connects back to the show. He said it seems that there are only a few places on television where one can find science in action, with people doing scientific work, such as the fictional drama *CSI* and the factual, but entertaining *Mythbusters*. He asked workshop participants what they see in *CSI* and *Mythbusters*. Are they a good thing, bad thing? "Who thinks *CSI* is a good thing from the perspective of informal chemistry education?" asked Carroll.

Paul Bryan said he is not a big devotee of *CSI* and *NCIS* but that he watches them occasionally. He thinks the show is connecting chemistry with something that students see as exciting. "Murder and mayhem and whatnot is much more exciting than test tubes and Erlenmeyer flasks," he said.

Steve Lyons observed that he thinks, on balance, *CSI* and *NCIS* are positive because they do show science being used in a creative way. However, he lamented that the creators of these shows feel that in order to make science or mathemat-

---

[6]For more information, see *www.thehistorymakers.com/* (accessed January 1, 2011).

[7]See *http://portal.acs.org/portal/PublicWebSite/education/outreach/ncw/CNBP_025198* (accessed December 1, 2010).

ics palatable for people, they have to put it in the context of a crime-solving program. He said, "I wish there was some way to create a more realistic science program that didn't have to shoehorn the science into that kind of program."

For example, he thought it would be great to show chemistry in a different place and time, such as the new fictional drama *Mad Men* does with advertising in the 1950s and 1960s. He said, "I think what is needed is for some creative person . . . to come along to look at science in a new way and create a world [for chemistry] as original as *Mad Men*, and not shoehorn science into a crime-fighting program."

Participants discussed how scientists are portrayed in TV shows in negative or in stereotypical roles. . . . However, Baisden mentioned an educational documentary television show that aired on PBS called *Connections* that depicted science and scientists in a positive way. She liked that show a lot, because it talked about scientific events, and then it connected them to societal benefits.

Lyons agreed that *Connections* was a wonderful program. He pointed out that it was British, and James Burke was the presenter. "He is very good at making surprising connections between these widely separated events in history and space." He had a sequel called *Connections II*. Bill Carroll mentioned that there was also a videogame associated with the show.

Carroll then asked participants what is needed to have a good entertainment program. He said, "You need good characters, you need a good reason for the show to exist. There needs to be some central organizing problem around which you can get people interested. Is there a way of doing that without murdering somebody? Can you make research interesting without showing the 100 times you do something and it doesn't work until the 101st time and it does? Is there a way of making that dramatic?"

Lyons said they were able to do that in the Percy Julian documentary, by focusing on highlights of his life. He said, "If we had done a film about the entirety of [Julians's] chemical career, it would have been pretty boring, because there were a lot of dull moments in that life. We just picked the high points."

Carroll followed up with another question, "How would you do [a show like Percy Julian] on a weekly [drama] series?"

Lyons replied that he wasn't sure. "Looking at *Mad Men* as an example, *Mad Men* is a series about an advertising agency. There are some moments when they are focused on the nuts and bolts of putting together an ad campaign for Pan Am or for Kodak or whoever the client is who walks in the door. There is a lot of dynamics among the characters who work for this agency that brings you back to the period in the 1950s and the 1960s, which is very realistically recreated by the costumes and the sets," he explained. What makes the series work, Lyons said, is that "it is not just about advertising, it is about those characters and their demons. The main character is a very troubled guy. Earlier in his life he changed his name in the war. He switched identities with a guy who was killed next to him in the war so he could escape his parents, and this has followed him for the rest of his life."

Lyons said that in a similar way, someone could make an interesting fictional but realistic series about chemists. However, he warned that it cannot simply be focused on the chemistry. Chemistry can be part of the story, but more importantly, there have to be real characters with interesting lives and stories.

Mark Griep said Lyon's idea reminded him of the 1930s and 1940s movie montages he has seen. For example, in the movie *Dr. Ehrlich's Magic Bullet*, about the discovery of "compound 606," it took the main character 606 tries to find the right antibiotic. In the movie, the discovery was shown as "a series of bubbling apparatus, guys working at benches, people writing in notebooks, and then finally the test works."

Formalizing Informal Education

Carroll changed topics and commented that formal education is highly organized and informal education seems to be rather hit or miss. He asked, "If the goal were to appreciate that more of the education happens informally, how could we do a better job of organizing that so that people come in contact with it more often and absorb more? Or does it simply have to be random?" Andrea Twiss-Brooks argued that some of the attraction of informal education is that it is not highly organized, but it is a good idea to organize the content so that people come in contact with it. She said, "Children have their days organized in school, but they often find their spark outside of school where it is not organized and they are able to use their own pace." She thinks it is a good idea though to have resources, such as takeaways that somebody could use during a blizzard. She said it is really important for informal education to develop and make those kinds of resources available.

Rosenberg mentioned the project he is involved in called SMILE, which stands for Science and Math Informal Learning Educators and the URL is Howtosmile.org. He said it is part of the NSDL, National Science Digital Library, and is meant to be a pathway to informal education resources. "We are trying to gather up activities that have been developed by museums and after-school programs around the country into one centralized place," he said.

"I think about [Carroll's] question a lot, actually. Most of the activities that we are cataloguing tend to be hit or miss in terms of, if you mix these two things together you see this effect. There is no higher level—if there is a higher-level explanation it tends to be lost in the doing and the seeing rather than the thinking," said Rosenberg. He said that one of the goals of their project is to try and make it (1) so that people don't keep reinventing the same activities, but can still compare the ones that have already been developed, and (2) to think about how to get to that next level for an activity. "The trick is, how do we take this informal field that is phenomenon based or story based in the case of media, and make it so that educators feel more comfortable trying to get the learner, not just the kid, but the learner thinking about that next level and making a bigger organizational pattern," said Rosenberg.

Carroll said that this related to Yancone's earlier point, about chemical magic versus using a demonstration to educate "that it is not just about the whiz-bang, but how do you use the demonstration to get the attention and then to say, this is what is going on?"

Rosenberg responded, "Because it is free choice, because the museum in particular tends to be 5 minutes here, 2 minutes there, or home activities or after school—it tends to not be very coherent." He is working on cataloging the activities in a more coherent manner so that an educator can start to think about what the learning goal might be for the activity, instead of just the phenomenon.

One difficulty for teachers is that they already have too much to do. He said that unless information is put in the hands of teachers in a highly organized way and the activities provided are easy to do, the uptake won't happen. He said that a goal of the SMILE program should be to figure out how you make the transfer of information easy and accessible, so that it fits into a teacher's lesson plan almost without thinking about it.

Rosenberg replied that what Carroll suggested is being addressed. The activities and resources being catalogued are open to everybody and are freely available online, and related activities are linked to each other. For example, there are the instructions for making Flubber, where Elmer's glue and borax are mixed together to make a silly putty-like polymer. However, the explanation about polymers in most of the write-ups is somewhat limited, so there are links to related activities, such as using cutout paper models of monomers that can be mixed up in a bag with some Scotch tape to form a polymer model. He said the hope is that more people will become aware that the activities are free and available online and that some will also add activities to the site.

Making Videos

Pat Thiel mentioned that for the last few years she has been teaching physical chemistry at the university level, typically to students who are in their early 20s. She has observed that students in this age group are interested in unscripted YouTube videos, especially those by their peers. These videos have loud music background and are badly edited. She said, "They love that stuff. It seems like the worse it is, the more they like it. They appreciate anything that I put on, because then they don't have to listen to me, but the more formal it is, the more professionally it is done, the more quiet they are and the more reserved they are in their reaction to it."

She said a group of participants was talking about this at lunch—that there should be some level of encouragement to people to try and put their personal science online, but not too formally, or else it is not going to be as appealing.

Carroll asked her if she could engage her students to make their own videos that could be used for later classes.

Thiel said she was not sure, but that she planned to go back from this workshop and organize her research group to capture its research activities in a YouTube video online and, she added, "make it as badly edited as I possibly can."

Lyons responded to Thiel's comment, "Your experience with these videos reinforces the point that I was making this morning. Web video is a wide-open world, and nobody really knows how people are going to respond. So producing badly edited chemistry videos with rock sound tracks might in fact be the best way to go. Rather than producing little *NOVA*-ettes, the way I approached it. That might be totally the wrong way to do it." He said it would be interesting for someone to experiment with different ways of using video to communicate chemistry and measure how people react to the different approaches.

Carroll then commented, "When I am talking to students, I will say, 'When you go to a party and somebody asks you what your major is and you say chemistry, what do people do?'" He said the response is usually, "Ew, that was hard, no, I didn't like that, I didn't like my high school teacher, I got a D in that. You must be a brain. It is all that same thing." He asked, "How can we do a better job as individuals of not getting to that moment, which I call the shutoff moment?"

He continued, "Part of it is to get people . . . to talk about themselves first, and then maybe you can talk about what you like about chemistry." It is something the ACS has tried to do with the chemistry ambassadors, to work with people on their elevator speeches—15 seconds that allows a chemist to tell people what he or she does in a way that does not induce the shutoff speech.

He asked, "How comfortable do each of you who work in a science-y area [feel] . . . with the elevator speech?"

Bryan commented, "You don't bring people to science by talking about science. You bring people to science by talking about something they are already interested in, and then you link it to science." As an example, he talked about his work on biofuels. He said, "It is very nerdy and nobody looks like the people in *NCIS* or *CSI*, not nearly as interesting . . . . What we do is really fascinating, and it is very much linked to things that people are interested in. So when people ask me what I do, I say, 'I am trying to save the world.' Then I can lead from that."

Bryan recommended that participants look up an article called the *Seven Triggers of Fascination*.[8] According to the author Sally Hogshead, what really fascinates people comes down to seven different things—or what Bryan called "hooks"—that grab their attention: lust, mystique, alarm, prestige, power, vice, and trust. He encouraged everyone to think about what they do that links to one of the seven triggers. "Once you have reeled them in, then you can start moving closely to the science, you have got them hooked," said Bryan.

[8]S. Hogshead. 2010. *Fascinate: Your 7 Triggers to Persuasion and Captivation.* New York: HarperCollins.

Lyons suggested that "maybe by the time you make the elevator speech, it is already too late, because those people you encounter on the elevator have a shutdown moment because they have been taught chemistry in high school and they react to it in a negative way."

He said that he thinks this is a two-part problem. "Part of the problem is reforming chemistry education from the ground up so that people don't have that experience. Then maybe you can make some headway on the informal side as well. But without reforming education too, you are always going to have the shutdown moment."

Carroll thanked Steve and said, "Perhaps we should close for the day by saying reforming chemical education might possibly be the topic of another symposium."

6

Chemistry in Video, in Movies, and on the Radio

"Although they enjoy explosions and things like that,
we get nearly as good a response from the audience in videos that show nothing but me sitting in my office."
–Martyn Poliakoff

As pointed out in the report *Learning Science in Informal Environments*,[1] informal or everyday science education "is the constellation of everyday activities and routines through which people often learn things related to science." Watching short videos on the web, watching movies in a theatre or on television, or listening to radio or audio podcasts, all present venues for everyday science learning. In these venues, the author and audience do not have an explicit agenda to engage in science education; rather, this happens by way of a desire to entertain or be entertained. In this session, workshop participants heard about three examples of informal science learning, which included an introduction of significant chemistry content in video on the web, on traditional and Internet-based radio, and in cinematic movies. **Martyn Poliakoff** from the University of Nottingham described how he and his team created the very successful Periodic Table of Videos on the Internet. **Jorge Salazar** of EarthSky Communications described his organization's efforts to provide a commercial-free way for scientists to communicate. **Mark Griep** from the University of Nebraska-Lincoln discussed his analysis of chemistry content in films.

THE PERIODIC TABLE OF VIDEOS

The first speaker of the day, via webcast, was Martyn Poliakoff, who presented from his office with his video journalist collaborator on Periodic Videos,[2] Brady Haran. Haran was also videoing Poliakoff during the presentation, which was later posted on the Periodic Videos YouTube channel.[3]

Poliakoff explained that his research interests are mainly in green chemistry—cleaner approaches for making chemicals and materials, particularly cleaner solvents. He has carried out a lot of research in the area of supercritical fluids, highly compressed carbon dioxide, which can be used as solvents for chemical reactions. Because green chemistry has direct impacts for the public, Poliakoff and his research group have long engaged in public outreach. Dr. Sam Tang is a public awareness scientist, whose job it is to help Poliakoff and his colleagues present science to the public. For example, he showed Tang in the Victoria Shopping Centre in the center of Nottingham demonstrating supercritical fluids just before Christmas. A video of Poliakoff demonstrating supercritical fluids on YouTube was recorded by Brady Haran (Figure 6-1) on his YouTube channel called "TestTube." It had been watched by nearly 50,000 people at the time of this workshop.

As a result of the success of that video (Haran and Poliakoff received an award for the website), Haran got the idea of making a periodic table of videos—a website where every element would have its own video. "I told him he was completely mad," Poliakoff said, but after some discussion Haran persuaded him it would be a good idea, and they were able to raise the funds to make the videos.

Poliakoff demonstrated how to navigate the website and YouTube channels. They began filming on June 9, 2008, and recorded the first 36 elements (at least his part of them) in 2 hours in his office. The website was completed on July 17, in slightly less than 6 weeks, because money was limited and had to be spent before the end of July. They made 120 videos,

[1]National Research Council. 2009. *Learning Science in Informal Environments: People, Places, and Pursuits*. Washington, DC: National Academies Press.

[2]For more information, see *www.periodicvideos.com/*. Also, see S. Rittter. 2008. Elements Achieve Internet Stardom. *Chemical and Engineering News 86*(37):42-43.

[3]*www.youtube.com/periodicvideos#p/u/42/6yT8kvHlgeg.*

FIGURE 6-1 Martin Poliakoff being recorded for PeriodicVideos by collaborator Brady Haran.
SOURCE: Martyn Poliakoff, University of Nottingham. ©All rights reserved by Periodic Videos.

including 118 elements, a trailer, and an introductory video, with a total running time of 4 hours, 7 minutes.

Before they were finished producing the videos, they had more than a half-million hits and a lot of publicity. At the time of this workshop, they had had at least 11 million hits, but the number is not totally accurate, because it doesn't account for instances where a class of schoolchildren have all watched at once.

They can also track the many countries in which the videos were being viewed, and many viewers provide comments. For example, one said, "I love your videos and from watching these videos I have learned more than [in] a full term of college," and another, "Videos like these [are] what makes me interested in school and better improving myself. Thank you." Haran actually downloaded all the comments for all the videos about 2 weeks before Poliakoff's presentation and analyzed the words. The top 100 words in frequency they found included chemistry, element, and love, "which is quite encouraging," Poliakoff said. Other words he mentioned were awesome, cool, and interesting, which he said "are not words that are normally associated with chemistry."

Poliakoff showed some of the early press coverage of the website, as well as a mention of the project in an international review of UK chemistry research (by the EPSRC [Engineering and Physical Sciences Research Council], the UK equivalent of the National Science Foundation [NSF]). The review said, "Particularly impressive was the presentation describing online outreach, including a YouTube video on the periodic table of elements that has already received greater than a million hits worldwide." The importance of this is that, in general, chemistry outreach is being appreciated more and more—"much more than people understand, than the researchers understand."

Poliakoff explained more about the features of the periodicvideos website; how people can view and watch videos on the periodicvideos website, and they can also look at them on YouTube. One of the added values of YouTube is the ability to track the number of views and numbers of subscribers. About an hour before his workshop presentation, Poliakoff found that the periodicvideos YouTube channel had 25,307 subscribers. To put that number in context, he compared it to the video channel for the Kelsey Football (soccer) Club, which he said is one of the leading clubs in the United Kingdom. He noted that the soccer club had about 4,000 fewer subscribers than periodicvideos. He said, "Chemistry, at least in this context, is considerably more popular than soccer."

In addition to the videos about the elements, the group has done special features—for example, on the medals of the Olympic games. "When the large Hadron Collider leaked helium and closed down we made the video to explain why," Poliakoff said. For the Nobel Prize in 2008, they had nearly 40,000 hits in one week, describing what the prize was about, which was more than the official Nobel Prize video got for that week. One of the most popular videos they made was called "Candles at Halloween."

Poliakoff discussed how they also put subtitles on video. In addition to ones in English and Spanish, he said they have more than a hundred videos subtitled in Portuguese, some in Turkish, and now even in Indonesian. Once a YouTube video is subtitled, it can be translated to other languages automatically with reasonable satisfaction. He said they are now trying to subtitle all of their videos.

Poliakoff's team has also made an effort to go on the road and visit famous laboratories. For example, one trip was to Darmstadt, where element 111 was discovered. They also make trips to schools and conferences, and they have even collaborated with the Broadway Cinema, which is the leading private independent cinema in Nottingham. They once did a live performance at the cinema. He showed a picture of Sam Tang demonstrating dry ice on the stage at the Broadway Cinema. Because of the success of that event, they have plans to do a similar performance at other venues. They also have been involved in exhibitions, where viewing stations have been set up at a science expo or museum and people can watch the periodic videos online. Polikoff suggested that perhaps in the future the videos could be available for in-flight entertainment on airplanes.

Poliakoff highlighted the periodic videos team (Figure 6-2), and ended by saying "these videos are unique. As far as we know there is nothing else like it. There is obviously good publicity for Nottingham [but] . . . I think the most important thing of all is they make chemistry fun."

FIGURE 6-2 Martyn Poliakoff and the Periodic Table of Videos team.
SOURCE: Martyn Poliakoff, University of Nottingham. ©All rights reserved by Periodic Videos.

EARTHSKY: A CLEAR VOICE FOR SCIENCE—CHEMISTRY ON THE RADIO DIAL AND ONLINE

Jorge Salazar talked about the role that media can play in helping get the word out from scientists, and chemists especially, to a broader audience. Salazar explained that EarthSky is a Science Media Company, which started off as a radio program founded by Deborah Byrd in 1991. Byrd is also the founder of the radio program StarDate, an astronomy program, which she started in 1978. After running 5,000 episodes of StarDate, Byrd decided to branch off from astronomy.

The basic idea of what EarthSky does is to interview scientists and let them describe their research in their own words. The program is listened to in all different formats, on commercial and public radio. Salazar explained, "People who might catch a clip of our EarthSky are not necessarily listening for science, are not necessarily wanting to listen to some science, it will just kind of sneak up on them and before they know it they will have heard a little bit of EarthSky." EarthSky was awarded the first ever award from the National Science Board for talking about research and making it relevant to people's everyday lives.

EarthSky creates what it calls "impressions," which refers to every encounter someone has with the program, "basically every time you hear or you see or you access" through the radio or Internet. Each month, EarthSky produces about 80 new podcasts. In addition, it produces both 90-second and 60-second radio spots to meet the needs of different radio stations. It also just started producing pieces in Spanish called "Cielo y Tierra." Overall, EarthSky has produced close to 7,000 broadcasts, and they are all available at EarthSky.org. In addition to interviews (all podcasts are archived), EarthSky has a blogging section, which includes posts from EarthSky as well as contributing scientists. Figure 6-3 shows a screen shot of the www.earthsky.org website.

Salazar described the effort EarthSky makes to build networks and figure out new ways to get the voices of scientists out to the public. They have one partnership with Google, in which they have a dedicated layer on the Google Sky.[4] The layer includes EarthSky audio podcasts. EarthSky links the interviews with astronomers, and the stellar object they discuss, with the coordinates for the object in Google Sky. They also want to expand to work with the Google Earth application. Other EarthSky partners that Salazar mentioned include the National Science Foundation, National Aeronautics and Space Administration, and National Oceanic and Atmospheric Administration.

In the United States, many Spanish stations carry "Cielo y Tierra." There are also satellite networks that broadcast EarthSky, such as the Voice of America and American Voices Radio. The EarthSky distribution network now includes about 2,000 affiliates worldwide, after basically starting from nothing. Salazar said, "I have been thinking about a lot of the ideas that have been presented at this workshop, and as Dr. Poliakoff has demonstrated, there is a lot of opportunity right now if you get in early before things get too structured."

"The challenge that media face is a public that really doesn't quite get what science is about," Salazar said. For example, more than 100 million Americans believe that astrology is a "sort of science,"[5] and 46 million Americans believe that the ocean is a source of fresh water.[6] The other challenge is that the media landscape is pretty noisy. It is difficult to make a connection with people, because there are so many different organizations and companies vying for the public's attention. At the same time, there are studies that show the public trusts scientists. Salazar mentioned a study which found that 85 percent of people surveyed think that scientific research is important.[7] He said it makes sense that scientists are looked to for guidance on difficult, complicated issues such as global warming and stem cell research.[8]

Salazar talked about one of the series that EarthSky did, with funding from the Camille and Henry Dreyfus Foundation, focused on scientists' green chemistry and sustainability. The American Chemical Society helped find the right people to interview. Four researchers were asked to talk about their work, which resulted in approximately 58,000,000 radio and Internet impressions of the scientists talking about green chemistry.

---

[4]For more information, see *www.google.com/sky/* (accessed April 27, 2011).
[5]National Science Foundation, 2006. Public Attitudes Survey.
[6]National Environmental Education & Training Foundation, 2005. Environmental Literacy in America.
[7]Virginia Commonwealth University. Center for Public Policy Survey, 2001, 2006.
[8]University of Chicago, 2006. National Opinion Research Center, General Social Survey,

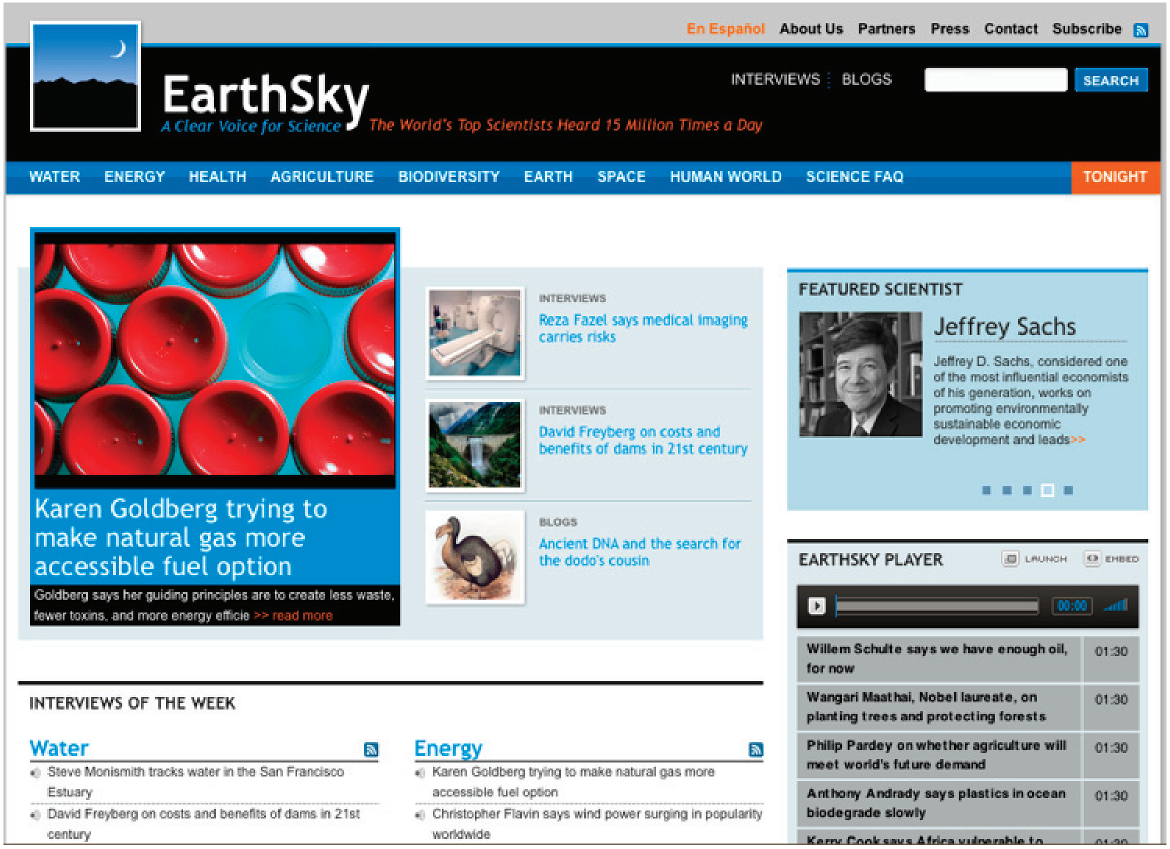


FIGURE 6-3 Screen shot of EarthSky.org.
SOURCE: Jorge Salazar, EarthSky.

Salazar described the EarthSky audience. Many listeners are from Voice of America around the world, including many listeners in China. One-third of them are via U.S. satellite, and the terrestrial stations, but a large chunk of its audience is international.

Another example of a chemistry-related series EarthSky produced with Oregon Public Broadcasting is called the Power of Small, which looked at the promise and pitfalls of nanotechnology. EarthSky interviewed scientists who were on this televised program and developed these small radio clips as well as extended interviews where people could listen to some of the issues that were being discussed in a little more depth. Salazar explained how EarthSky is constantly looking for a relevancy factor. "I think it is really important when chemists want to tell their story to be able to connect it to something that people are really interested in."

"Radio is still relevant," Salazar explained. Media are constantly changing, but a lot of people still listen to the radio. For example, in one week EarthSky generates about 32 million impressions, which is more people than watch *American Idol*. "This is not to say that one is necessarily better than the other, but that there are different ways to do it, and EarthSky can reach a lot of people with the messages that scientists want to give," Salazar added.

Looking to the future, social media are where a lot of focus will be for EarthSky. This includes ways to be able to get information through mobile devices, such as iPads and iPhones. Salazar said, "Our goal is to reach more people. . . . We are looking at this new media, social media, and we are jumping headfirst." The reasons for doing this are pretty obvious, given the growth and reach of Facebook and other media platforms, such as YouTube and Twitter. More importantly, he said, is "the people who use this media a lot tend to be well-educated and what media people call 'influencers,' people who influence a lot of other people. So when you can get to these people, your message can really spread quickly."

Questions and Answers

Steve Lyons asked Salazar to estimate how many scientists interviewed by EarthSky are chemists, compared to other sciences. Salazar said he didn't have that count, but chemistry is probably a pretty small chunk of what EarthSky has done.

Pat Thiel, Iowa State University, asked about coverage of basic versus applied research, with basic research being where the practical application is not always immediately obvious. She noted that some of the examples Salazar showed seemed to feature mostly applied research. She wondered if basic research would be "left in the dust" when it comes to communicating with new media.

Salazar replied that they don't neglect basic research advances in science, but that one of the challenges they face is looking for relevance. He said, "You need that, otherwise people stop listening." He mentioned one clip in a series of programs they did at Cornell University, called "Chronicles of a Science Experiment." Over the course of a year and a half, EarthSky followed a postdoctorate chemist, Aaron Strickland, in 8-minute podcasts based on 45-minute interviews. He said the point of the podcast wasn't to talk about any discovery or to talk about how this new thing that chemists are doing is relevant to people." The aim was to try to show scientists as real people struggling with these really fascinating problems over a long period of time. "It was kind of a human story, but it was challenging, being able to present basic research like that," he added.

CHEMISTRY IN THE MOVIES

Mark Griep discussed how he, in collaboration with his wife Marjorie Mikasen, wrote the book called *ReAction! Chemistry in the Movies* published by Oxford University Press in 2009. The research was funded by the Alfred P. Sloan Foundation. Griep explained, "We like movies, we watch a lot of movies." They took a list of more than 1,000 movies, watched about 400 of them, and then chose 110 movies to examine in detail for the chemical, psychological, historical, and social context. Griep also considered how a chemistry instructor might use Hollywood feature films in the classroom to teach chemistry.

"It's Called GOOP. The Real Name Is a Foot Long"

The basis of the approach Griep took is that movies are mediators of public understanding of everything, not just science. Filmmakers create movies for different reasons, with the ultimate goal of creating something that people want to see. They might want to tell a particular story or just want to make a lot of money. He explained that movies are great at placing any theme within a social context, because movies are mostly about people. Movies show how society views and understands chemistry, because filmmakers are going to choose stereotypes that are going to be useful for driving the story forward.

The movie that got Griep and Mikasen started on their project was watching an Elvis Presley film from 1967, called *Clambake*. Griep described it as a generic Elvis movie, except in this case Elvis happened to be a chemist. In the movie, Elvis states, "I am an engineer," which Griep explained means he is a chemical engineer because there are a lot of bubbling apparatuses in back of him. Elvis tries to develop a superhard, superfast drying varnish that he plans to put on a boat to win a race, which will win over his love interest and his father's respect. "Now, this is chemistry at its finest," Griep said.

At some point earlier in the movie Elvis says the varnish is called "GOOP, the real name is a foot long." Elvis sings a song at one point, surrounded by beautiful women, and within the song he names the molecule, "glycol oxonic phosphate is the latest scoop, but that's all right, girls, you can call it GOOP."

Griep said that caught his attention. He stopped and rewound the movie to listen to the word again and then tried to draw the molecule—but could not do it. The thought of the chemical name haunted him for months. One day, he had the idea that maybe "glycol oxonic phosphate" is a special inside word that they use in the varnish industry. He did some research on varnishes and found out that one of the oldest varnishes is linseed oil, which is rich in linoleic triglyceride. He said the way that linseed oil works is you paint it on and then, slowly, oxygen from the atmosphere reacts with the double bonds to cross-link the molecules together, resulting in a hard surface. "Okay, great, I learned a little bit about varnishes because of Elvis," he said. They then watched the movie again to see if there might be another character in this movie or maybe a prop that would provide more clues. Eventually, Griep and Mikasen came across other clues that allowed Griep to come up with the structure of an omega-3 fatty acid type epoxy, when combined together could make GOOP (Figure 6-4).

That experience, watching and analyzing the chemistry in *Clambake*, led Griep and Mikasen to start watching more movies where they thought they might find chemistry. Griep said, "By the time we had 30 movies on our list, I thought okay we are going to collect 60 total movies, that is all there is going to be in the whole world, and I am going to write this paper for the *Journal of Chemical Education*, and I would be done. Well, 1,500 movies are now on my list."

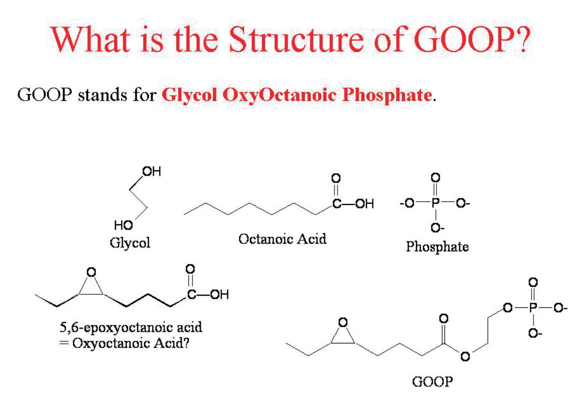


FIGURE 6-4 Comparison of real chemicals with the fictional "GOOP" molecule in the Elvis Presley movie *Clambake*.
SOURCE: Mark Griep, University of Nebraska-Lincoln.

TABLE 6-1 Themes and Genres of the Movies Discussed in Griep's and Mikasen's Book *ReAction! Chemistry in the Movies*

Book Chapter	Chemical Theme	Movie Genre Signatures
Dark Side		
1	Jekyll and Hyde	9 horror, 5 sci-fi, 4 drama
2	Invisible man	6 sci-fi, 5 horror, 4 [black] comedy, 4 thriller
3	Chemical weapons & terrorism	8 thriller, 6 drama
4	Bad companies	8 drama, 4 thriller
5	Addiction & psychoactives	8 drama
		TOTAL: 26 drama, 16 thriller, 14 horror
Bright Side		
6	Inventors	8 comedy
7	Forensics	7 drama, 7 mystery, 7 thriller, 5 action, 5 crime
8	Chemistry classroom	7 comedy, 4 sci-fi, 4 romance
9	Good researchers	5 drama, 4 comedy
10	Drug discovery	8 drama, 8 sci-fi, 6 horror, 6 comedy
		TOTAL: 25 comedy, 18 drama, variety

SOURCE: Mark Griep, University of Nebraska-Lincoln.

Chemistry in Movies

"So what qualifies as chemistry in the movies?" asked Griep. He said that they set the bar low; there may be a character identified as a chemist or sometimes a chemical engineer. A character might mention an element, isotope, compound, or anything simple. "But you need rules for exclusion," Griep said "because some things are so ubiquitous," such as gold, diamonds, and water. However, he said that sometimes gold is interesting. For example, Iron Man is a gold-titanium alloy.

To select what to include in the book, Griep and Mikasen made a list of movies they watched that might be interesting and then considered the criteria, "Is it recent? Is there enough chemistry to talk about? Is it a pretty good movie? Are there other elements in this movie?" Using these criteria, they whittled the list down to about 70 movies and then grouped them according to some main themes represented in the movies.

Griep and Mikasen grouped the movies they watched into a dark side and a bright side and according to chemical theme, as shown in Table 6-1. Roughly, about 50 percent of the time chemists and chemistry are presented in a positive way, and 50 percent of the time they are presented in a negative way. He said this essentially breaks down according to genres; the chemistry in horror, sci-fi, and drama tends to be negative, while the chemistry in comedy tends to be positive.

After conducting their research on movies, Griep and Mikasen were surprised to find three things:

1. There are many chemists and a great deal of chemistry in the movies.
2. Fictional chemicals in the movies are based on real chemicals.
3. There are many women chemists in the movies.

Griep explained that when chemists appear in movies, they tend to have a white lab coat, they work obsessively, and they typically have colored solutions bubbling in the apparatus behind them. When chemists are portrayed on the bright side, they tend to be professors, inventors, criminologists, or researchers. Professors will be involved in explosions as a result of synthesizing a product that solves a personal problem. Inventor characters often want to create a commercially viable oxymoronic product, such as a nonsticking glue or elastic glass. Criminologists use chemistry to eliminate possibilities; however, Griep said, they don't solve the problem. "How do you solve murder mysteries in movies? Intuition, it is always intuition, it has nothing to do with chemistry." The ultimate glorifying version of chemistry in the movies, he said, is "the researcher who is working on something good to solve society's problems. And I think everyone in this room would be happy if all chemistry in the movies had this image of chemists' solving problems."

Griep explained that there is a great deal of chemistry in the movies. For example, in the 1992 film *Medicine Man*, a botanist goes to South America for a couple of years to work for a pharmaceutical company and look for anticarcinogens. He is then joined by a biochemist named Dr. Rae Crane, who fires up her gas chromatography (GC) mass spectrometer to analyze samples in the middle of the South American jungle. Somehow they are able to determine that one of the compounds ("Peak 37") in their mixture has anticancer activity. They show the wonderful chemical structure of the compound (Figure 6-5), a fictional molecule, that Griep said is chemically correct—that is, no rules of chemistry are broken, such as a carbon with five bonds.

The second major surprise for Griep and Mikasen was that the fictional chemicals are for the most part based on real chemicals. For example, the 1961 version of the movie

Absentminded Professor introduced "flubber." The main character (played by Fred McMurray) sees the equation $H = E - P$ on his blackboard, but it should be $H = E + P$. So the professor adjusts the dials on the machine he has for it to be plus, not minus, and it explodes and he makes rubber that flies. Griep looked for clues in this movie and noticed a notebook where the professor wrote the structure of butadiene (rubber). He said, "So 'flubber' is flying rubber, based on real rubber. This is 1961 and World War II, a lot of synthetic rubbers, this is fantastic stuff."

The third surprise was that there are many women chemists in the movies. Figure 6-6 shows the number of movies they found featuring a woman as a chemist versus time and the percentage of physical sciences doctorates earned by women in the United States. Griep said, "You can see that in 1920 the first woman chemist made her appearance, and then from 1930 to about 1965 there were quite a few; it dropped down to very low numbers and then [they] made their appearance again in 1995, and they are going up. And it is continuing to go up, with actually a very good increase in women chemists in the movies."

"But this does not reflect at all the percentage of women in the physical sciences who are receiving Ph.D.s in chemistry," Griep said. The number of women earning Ph.D.s was low during the period when there were many women chemists in the movies; now, he said, "they are very high and the movies have lagged behind. Socially, making movies has lagged behind in terms of the women chemists."

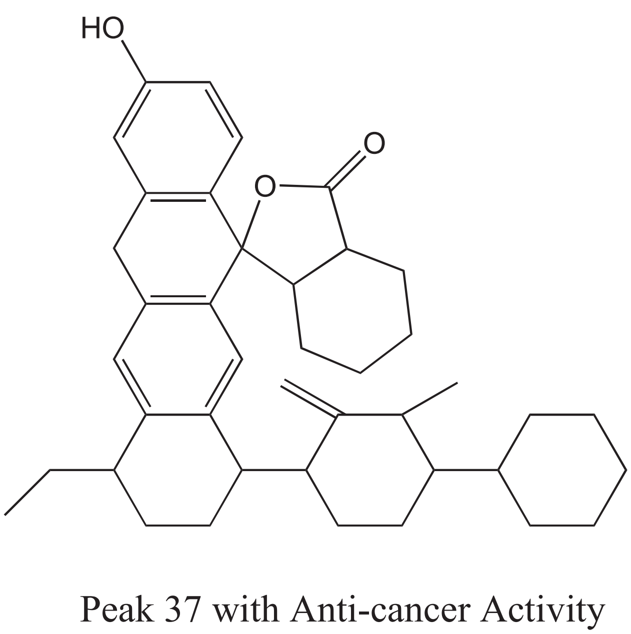


FIGURE 6-5 Structure of a fictional anticancer drug in the 1992 film *Medicine Man*.
SOURCE: Mark Griep, University of Nebraska-Lincoln.

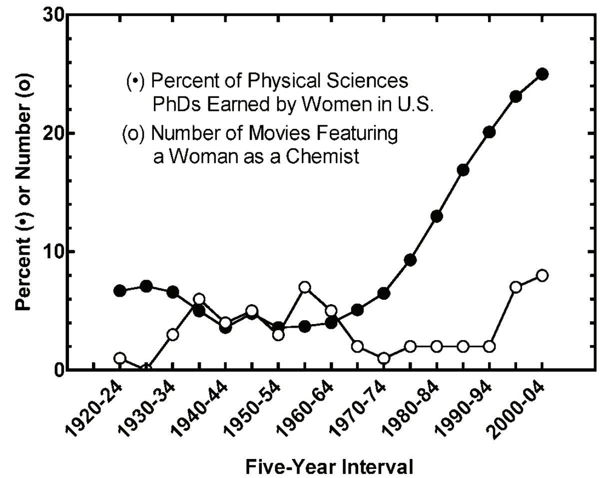


FIGURE 6-6 Women chemists in the movies. Number of movies featuring a woman as a chemist versus percentage of physical sciences Ph.D.s earned by women in the United States.
SOURCE: Mark Griep, University of Nebraska-Lincoln.

Griep listed the names of some of the movies featuring women chemists: *The Blooming Angel* (1920), *Beauty for the Asking* (1939), *Wink of an Eye* (1958), and *Caprice* (1966). However, he said, "if you go to an Internet movie database and you type in chemist you are not going to find these four movies," because each movie involves a woman making cosmetics. Another category of women chemists in movies he described is where female chemists have a masculine or gender-neutral name, such as Dr. Rae Crane in *Medicine Man*.

Griep said he believes the future of chemistry in movies is very bright given recent trends. For example, he said 2009 was a great year for chemistry in the movies. All of the following movies had some chemistry (a lot of it on the bright side) featured in them: *Married Life*; *Duplicity*; *Good Hair*; *Whatever Works*; *Harry Potter and the Half-Blood Prince*; *The Informant!*; *Moon*; *Avatar*; *District 9*; and *Sherlock Holmes*. He also noted that the actors portraying chemists continue to become more diverse, and there are more women and more people of color who are chemists in the movies.

Griep ended by mentioning that the Alfred P. Sloan Foundation has funded the Science Screenwriting Programs and awards, which has supported the production of many chemistry films. In addition, he noted that the National Academy of Sciences now has the Science and Entertainment Exchange,[9] "which tries to bring scientists in collaboration with filmmakers to improve the content or come up with the best type of scientific themes that you could put in the movies—what are the most engaging themes."

[9]For more information, see *www.scienceandentertainmentexchange.org/* (accessed January 27, 2011).

OPEN DISCUSSION 5

Poliakoff commented that his brother is a playwright and that he had to write some chemistry text for his brother's play that was performed by the National Theater in the United Kingdom. Polikoff said, "On the opening night I was the only person in the audience who burst out laughing when one of the characters said 'hectofloral isopropanol.'"

Bill Carroll asked Poliakoff about going from fun and exciting videos to instilling a real interest in chemistry. He said, "My question is, Do you see any transference from the people who enjoy the brief videos about the elements, to an interest in doing reactions with them, and doing more chemistry?"

Poliakoff said they have not done any research but have just looked at people's responses to the videos. They found that although viewers enjoy explosions and things like that, they get nearly as good a response from the audience in videos that show nothing but Poliakoff sitting in his office. One of the most popular videos he has made is one on the "Chemistry of Candles," which shows Poliakoff lighting a candle and blowing it out in his office.

A lot of people are very interested in videos, but it is difficult to know whether this translates into an actual lasting interest, Polikoff noted. He showed an e-mail posted by a Korean student, who said that people in his chemistry class thought it was really boring and that chemistry is pointless until they had seen the videos and found that chemistry was really interesting.

Brady Haran said they find a lot of interest in the films where they blow things up or do something that might be a bit fun and crazy, but there is also interest in ones where they are just talking through something quite scientific and dense. A lot of the people who first stumble over a video that had an explosion in it have said, "I like the explosion but I also liked what that crazy-haired professor was saying in between the explosion, I'm going to watch more of this." "They subscribe [to the YouTube channel] and they become long-term viewers. And they may have been pulled in by something spectacular, but then they get into the more dense chemistry."

Following up on Griep's talk, Bill Carroll observed that the "Jekyll and Hyde" metaphor also applies to the discussions about the perception of chemistry—the Jekyll side that chemists want to promote versus the Hyde side that they get stuck with a lot.

Sharon Haynie commented on the stealth characteristic of radio, where listeners tend to listen passively, in contrast to watching a video or playing a game, which tends to involve people intentionally seeking out the content. Radio can catch listeners by surprise as one program transitions to another. She asked Salazar to discuss how EarthSky is transitioning from building the surprise to building an intentional listening audience.

Salazar replied that they are still trying to figure that out. They have had success in building up the broadcast network but are still learning about social media—YouTube, Twitter, and others. He said, "There are people who want to learn more about things like chemistry, about things like science, they love hearing this stuff from the scientists themselves. They don't necessarily like people like me, the media, telling them about this kind of stuff. They want Einstein to tell them about chemistry, I guess, in some ways, Dr. Poliakoff." EarthSky tries to show that there are a lot of different people who are doing science. "We are still building, and we are still learning," he added.

Poliakoff commented that there are about 1,000 people following periodicvideos on Twitter. "I think that I would never get the research done," he said, but Brady posts to Twitter quite regularly, and they now have about 1,000 followers and a similar number of fans on Facebook. He noted the people who do subscribe really seem to stay as followers, and from their comments it is evident that they have watched quite a lot of the videos.

Nancy Blount, American Chemical Society, asked Griep if, from his work analyzing chemistry in the movies, he thinks that an effective message about chemistry is being delivered. Griep responsed: "I think usually the chemistry that is presented in these movies is correct," such as the molecule in *Medicine Man*. However, the public does not know it is chemically correct. They also do not know that it is a fictional molecule.

When movies use chemistry, it is because they know the public is going to accept it as true. In general, the public has no way of judging whether it is true, since they really do not have the chemical knowledge. Griep thinks the reason there is so much chemistry in these comedies is that the filmmakers can say these true chemical things, and then add a little bit of gobbledygook to make it fictional, such as some special property. Then they build their comedy on that.

"I think one thing that we can do as chemists is to use these movie clips in the classroom," Griep said. Everybody watches movies, and they probably know more about movie actors than they know about chemistry. He said that if these movie clips were shown in the classroom, there would be an automatic connection between chemistry and movies, and that would link into the larger network most people have with movies. It then provides an opportunity to explain the real chemistry, "and people always love that," said Griep.

Poliakoff added that a simple explanation for why chemistry is correct in films is because chemistry is difficult to make up. It is like somebody having characters speak a foreign language in a film—it has to be correct.

7

Tools and Techniques

"If you are not on a superhighway these days, it is going to be really hard for people to find you"
—Robert Hone

This session explored opportunities for expanding informal chemistry education. **Robert Hone**, Red Hill Studios, discussed advanced video gaming; **Deborah Illman**, University of Washington, spoke about a targeted writing program she has developed for chemists; and **Andrea Twiss-Brooks**, University of Chicago, talked about the traditional and changing roles of librarians and libraries in supporting informal learning.

GAMES THAT MATTER

Robert Hone said that Red Hill develops museum exhibits, documentary films, online games, and more. It also does work for a large publishing company. For example, his company did the latest run of chemistry tutorials for the Zumdahl (general chemistry) books.

Hone discussed the current grants of Red Hill Studios. One is from the National Science Foundation (NSF) to create BioArcade, currently on PBSkids.org. The other is a Reese Grant for the studio to look at how to make games adaptive for different needs. For example, Red Hill builds physical therapy games using current game platforms, such as for people with Parkinson's disease using the Wii and the Wii Fit for kids with cerebral palsy. "It's very rewarding work," Hone said.

Red Hill calls the educational games it develops "games that matter." The studio has focused on games because there is a lot of interest right now. "I think there is a lot of work, good foundation work to be done. I think the field really has been moving along pretty much on the level of 'if it sells it's good,' and I think there is a research foundation that could be built," Hone said. Hone explained that in the past education and gaming were thought of as two different and unrelated activities, but that is changing.

Red Hill is currently involved in seven different projects, including the physical therapy games, cognitive games for multiple sclerosis, and games for integrated pest management, which is an NSF grant for the University of Arizona. The studio is also working with CISCO on networking training, the California Science Center, college-level math games for Addison Wesley, and an informal biology-based game for PBS, which Hone mentioned earlier.

The basic way that games work is to match ability and difficulty: as the ability rises, the difficulty should increase. Hone recalled how the founder of Electronic Arts (EA) once described a computer game like a tennis match where the score is 7-6, 6-7, 7-6. The game needs to be difficult and challenging. He said, "If it is easy, it is boring." However, if it is too hard the player will be frustrated and drop out. He said if that match of difficulty is achieved, the player gets into a flow state, which is a highly mindful focused state. Games are addictive, because they keep putting kids back into a flow state.

Another metaphor Hone said to consider, in terms of easy or matching difficulty, is skiing. "When you are learning, you want a very easy slope, but you can't stop there. You have to build the slopes for the expert skier," he said, "you are building a whole mountain for a game. You are building everything from getting started, all the way to the most difficult. Then you give them a progression, because if you get them hooked, you want to keep them hooked. You want to keep them going."

One of the ways to do that is to build a series of individual levels, such as easy, medium, and hard, or it can be many levels. Hone gave an example of a game Red Hill released that had 60 levels, instead of 3. This is common for consumer video games, which often have 40, 50, 60 levels. He said consumer games "plan for that; they build the mountain, they don't just build one slope."

In the Lifeboat to Mars game, Red Hill created two simulations. One is about microbial function; the other is about ecosystem dynamics. There are a series of levels for each game in which the player must complete the levels in order. In the microbial system, the player has to understand that he or she is going to need mitochondria to process food; otherwise there is no movement to the next level. He said this is called a forced progression. Since the game was launched in early January, Hone said more than 100,000 game levels have been played. In addition, players are provided the tools to build their own levels and upload to PBS for other kids to play. Hone said that more than 1,200 levels have been built.

Another model that Red Hill is considering is something called concept maps. For example, Hone said, "You would have to learn about mass, and then you have to learn about speed before you can learn about momentum. You combine the concepts—and not just in a linear path."

Hone then presented some things to consider when trying to make games interesting. One of the challenges is there are many different ways to deliver feedback to the player. He said that "the worst thing you can do is give the answer away. They want the thing to be tough. They are struggling at it; you give them the answers, is like telling them 'who done it.' You want to hold that back, you want to create that challenge." Hone said people who want to design games often worry that they will be too hard. It's important to give the players a chance, so they will try again. At the same time, he explained, "if they fail, they are not just going to walk away. It is a game. There is an expectation that sometimes you are going to fail and you got to try again."

It is also not necessary for the player to always master or focus on the intended educational goal, said Hone. Sometimes, neutral gaming elements can be included that simply keep the player engaged. For example, Red Hill created a game for Dragonfly TV, in collaboration with Twin Cities Public Television and funded by NSF. The goal of the program is to move around a space station and try to fix things, with only a limited amount of fuel. To make it more challenging, a timer was added in the face of the oxygen tank. The player then has to balance doing the task quickly, without using up all the fuel. Hone said, "We created a situation where you can't optimize for one or the other, you have to look at the combined optimization. That makes it a game." He explained that the timer is a noneducational component, but it makes the game.

Hone mentioned some ideas for possible chemistry games, especially targeted at middle school age, because kids at this age are not cynical and are more open; they will play games over and over again. They are also still at a place where it is possible to cover enough science to make it worthwhile. For middle schoolers, he suggested to

- Tie games to climate change or energy use,
- Use age-appropriate graphics and content,
- Develop or adopt learning progression (e.g., American Association for the Advancement of Science [AAAS] Atlas),
- Build sets of levels that cover the learning progression, and
- Create tools for players to build their own levels (modding).

Hone also emphasized that after going through the trouble to make a game to access on the Internet, it is important to put the game on a well-trafficked site. For example, Red Hill has a strong relationship with PBSKids.org, a popular website for children. "If you are not on a superhighway these days, it is going to be really hard for people to find you," he added.

The high school or college level can also be targeted. Hone mentioned work Red Hill is doing with Benjamin Cummings Houghton and games for Addison Wesley. For this age group, he suggested to

- Align with educational publishers,
- Tie into existing textbook as additional practice,
- Assign the game as homework,
- Design games as formative assessments of conceptual understanding (with reporting back to the teacher), and
- Create tools for players to build their own levels (modding).

Hone cautioned that games are not yet appropriate for teaching content. He said, "I think it is not as time efficient as other instructional technologies . . . if you play Civilization you will not learn history as well as reading it in a history book." While games augment other forms of education, they are not going to replace anything just yet, he added.[1]

"We are doing the assessment inside games very carefully under the hood so we don't wreck the designer-player contract," Hone said. In a formal instructional environment, students are being assessed all the time with quizzes and tests. They can be given a couple of questions right after being delivered some content to make sure they are paying attention, but this cannot be done the same way in a game. The approach has to be different.

Hone warned, "Please don't shoehorn things into a game." Games have their purpose, they're good for either practice problems or forms of assessment. He said, "Don't try and pick your hardest topic that you can't teach any other way, and think just because it is a game that will make it easier. If it is hard in the other environments, it is probably hard as a game." Games that provide supplemental learning opportunities can increase student engagement. He added that games

[1]For the recent report on this topic, see National Research Council. 2010. *The Rise of Games and High Performance Computing for Modeling and Simulation*. Washington, DC: National Academies Press. Available online *at www.nap.edu/catalog.php?record_id=12816* (accessed January 27, 2011).

in general should be simulation based, because then the marginal cost of creating an additional level is low.

Hone noted that people are just beginning to understand that the Internet is a great distribution system as well as a great listening system. He said, "That is why Google is so powerful; they are listening, they are not talking." By listening, examples can be put out there; then the responses can be monitored. He added, "Put a challenge and see how they react to it."

For example, Hone said that his studio plans to put out two different versions of a game to PBSKids. They arranged to run trials where one-half of the kids using the site are going to see version A and the other half are going to see version B. There will be about 5,000 kids per version. He noted, "When you go into a classroom and you get 5,000 [participants] you would be doing this for a decade, but online you are able to get those kinds of numbers fairly easily."

Questions and Answers

Paul Barbara, University of Texas at Austin, asked Hone if he considered whether there could be effective video game or cyber models that would have some of the advantage of things like the FIRST® Robotics[2] and the FIRST® Lego Leagues, where there is a competition to build something to solve a specific practical problem, such as moving people in cities or building a prosthetic.

Hone replied that he is a big fan of FIRST® Robotics and that he thinks it could work. He mentioned a collaboration Red Hill has with PBSKids.org to build an "ecocity" that is sustainable.

Barbara then asked Hone whether there are actual problems to solve where many people are needed to help solve them that could be part of a video game.

Hone responded that he is familiar with the concept, but that to ask kids to cure cancer is probably setting the bar a little too high. "I would say that what you are doing with games for kids should be something that gets them excited about the field so they pay attention in class," Hone said.

CULTIVATING CHEMISTRY COMMUNICATION LEADERS

Deborah Illman talked about the Chemistry Communication Leadership Institute she created at the University of Washington. The project is funded by the NSF Chemistry Division, with the goal to cultivate a new generation of chemistry communication leaders. The approach builds on what she has found to be the most effective strategies from her experience teaching science news and fiction writing at the University of Washington (UW), for the past 10 years. Illman has combined these in an "intensive, hands-on, week-long sort of boot camp, with the goal of not only giving students a grounding in some communication techniques, but then equipping them with some resources and curriculum materials to bring back to their institutions to share with others during the following year and beyond."

The idea for the institute was motivated by the International Year of Chemistry in 2011, and also by the fact that over the years she has noticed that chemistry lags behind the bio- and health sciences in enrollment in the University of Washington writing program. Over a recent 10-year period, Illman analyzed the disciplines from which the students in her three courses on science news and on fiction writing were coming. She found that students in bio-related sciences were the largest subscribers, at 25 percent of the 465 students enrolled. At the same time, she found that chemistry students were only about 4 percent of the class enrollment, or about 20 students over a 10-year period. She note that that number "is actually double what it would have been if I had not gone over to the chemistry department and talked to the advisers and tried to rustle up some chemistry students to take these courses."

Yet one thing that surprised her is that most of the students who come to these courses to learn about writing for general audiences were from the sciences and engineering. They was a slight majority there, whereas other units such as communication, journalism, English, creative writing, economics, history, et cetera, comprised about 42 percent of the participants over the years on average.

Illman then extracted some of the approaches used in her classes, combined them into a week-long experience, targeted a group of postdoctoral researchers in chemistry from across the country, and held the first Chemistry Communication Leadership Institute, sponsored by NSF, the American Chemical Society (ACS), and UW, in September 2009.

An informal survey of the institute participants showed that 20 percent of them had heard a little about the structure of news writing before, but none of them had ever heard of a public information officer or knew anything about the process of communicating through journalists, such as using a press release. By the time they finished the course, they had written and revised an actual press release, and also had a chance to learn and practice a range of other communication techniques.

The topics Illman and other presenters covered in the week-long experience included the following:

- The science communication process
- Challenges of communicating chemistry
- Understanding the journalist's world
- Public information officers and press releases
- Newsworthiness and the structure of news writing
- Interviews
- Using digital media to reach broader audiences

[2]For more information about FIRST® Robotics, see *www.usfirst.org/* (accessed December 3, 2010).

- Writing for radio and podcasts
- Freelancing and writing the query letter
- Writing and editing processes: structure and clarity

For the classes, Illman was joined by Ivan Amato; Robert Service from *Science*; Alan Boyle, who is the science editor from MSNBC.com; Jim Gates, a reporter from KUOW (the local National Public Radio [NPR] station); and two public information officers from the University of Washington.

One of the techniques and activities used in the program was for students to create a press release. Authors of two papers originated at UW were brought in to answer questions from the students, who then wrote a press release based on the interviews. The class critiqued the press releases along with the headline. The headline is a critical part, because it makes the students focus on why anyone should care about it.

Students also had to write a freelance proposal, which they did with the help of a radio reporter. They also worked on a 90-second elevator talk, which was recorded and played back and critiqued. One unique activity students did was participate in interview simulations, which Illman said was probably the most successful part of the whole program.

Illman explained to workshop participants about the rationale for the activities she selected and the rationale for her approach to teaching science news and nonfiction writing more generally. She has worked with a lot of science graduate students over the years, and has noticed that the most frequent problems encountered in the writings of science researchers have to do with issues of audience. They tend to use a lot of jargon, familiar terms used in unfamiliar ways, too much technical detail, inadequate explanations and metaphors, and inappropriate selection and ordering of information. The activities she put together for the chemistry communication institute are exercises that address all of those issues.

Illman has also found that most science graduate students (based on informal polling in her writing classes) have either very little or no contact with nonscientists on a daily basis. As a result, there is very little opportunity for students to develop mental models of what general audiences know or do not know and what is appropriate information to share with them. "In fact, they come to me and they ask me, 'How do I know what my audience knows?' That kind of got the ball rolling and thinking about it," Illman added.

Illman talked about the interview simulations. The students served as journalists and prepared an interview guide they could use with some real scenarios and real content that Illman selected in advance. They were to interview sources, played by experienced actors from a consulting firm specializing in high-stakes communication training. She said she supplied the actors with real scenarios based on actual press releases, which they researched and rehearsed. The scenarios chosen depicted commonly encountered source personality types—the reluctant source, the tangential talker, the wary source, and the "deriving everything from first principles" source. The actors depicted these personalities in relating the content for their scenario and rotated through small groups of postdocs; the postdocs played the journalists, interviewed these sources, and then did a debriefing.

The interview simulations were the most highly rated of all their activities. They said it helped a lot to walk a bit in the shoes of the journalists. Overall, the institute received high ratings from all the participants. They all said they would recommend the institute to others and would be more likely to engage in communication in their careers as a result of the program. Illman provided quotes from a few institute participants:

- "The guest speakers introduced me into a world which is completely in the dark for most researchers; knowing the process of publication and how it works was extremely valuable."
- "The most important aspect for chemists is the lifting of the veil on how science news is published, what are the steps and motivations, who are cleared in the process."
- "I feel like I have a writing network now."

After the institute, the postdocs created many freelance products, which Illman showed. For example, an article by postdoc Adam Tenderhold titled "Scientists Develop Method to Identify Tissue During Surgery in Real Time" appeared in the *Vernal Express* in October 2009. Illman gathered updates from the participants as part of a midyear review of the program where she interviewed all the participants to see what they had been doing. There were a number of freelance pieces, some of them for Illman's magazine, *Northwest Science and Technology*; one for the Scripps Publication; and another for a Utah newspaper.

Illman also attempted to quantify the kinds and numbers of activities, and the number of people directly and indirectly affected by the postdocs' sharing the institute content with people at their institutions. She found that about 225 people by midyear had directly received the institute content from the postdocs. Then there were a number of indirect effects where the postdocs undertook activities that delivered science and chemistry content to broader audiences—2,800 for example in the outreach projects and events, the freelance writing, and so on. In terms of reaching more general audiences, she noted that the University of Washington website got about 10,000 visits in April. There was also coverage of the program in the media on blogs, television stations, and TV websites—but she said it was hard to estimate the impact of that.

Participants were also asked about the challenges they faced in applying the institute content during the year. One of the major challenges, which they expected for postdocs, was the time constraints of their jobs and job changes. At the same time, she said they noted that the institute preparation really enhanced their job-hunting skills. Some participants encountered resistance in their departments. Others found it hard to get started in freelancing. There was also the expected loss of momentum once they got back to daily life.

In terms of improvements to the program, a lot of them said they would like periodic reminders. Some of them said they would like help in brokering freelancing opportunities and more guidance on how to share or how to teach communication in the context of chemistry and to show how it is relevant.

Illman said she has a Phase II proposal pending that would offer five more institute sessions over the next 2 years, with the goal of reaching about a hundred chemists. She would also like to transition the institute to a self-sustaining operation, broaden participation to include faculty members who can help institutionalize this information in their departments, and study the effects for a broader group of participants.

The last thing Illman mentioned was another project she is working on that is somewhat synergistic with her writing institute. It is an ongoing NSF project to use mental models' research methodology to study perceptions of the audience in decision making in science and technology communications. It is meant to prepare experts and novices to figure out how their mental models affect their decision making when they are crafting messages for general audiences.

Questions & Answers

Sharon Haynie was struck by the small number of chemistry and engineering students that participate in Illman's writing classes. She asked, "Are there curriculum barriers or things that don't allow them to access—make it hard for them to participate in your course?"

Illman replied, "For the engineers, the answer is a resounding yes. For the chemists, I think it is just not on the radar screen." She said she hasn't studied that, but thinks it would be a good thing to try to find out. Every time she went to talk to advisers about it, it would yield about four or five students. She recalled one quarter in which she had five chemistry graduate students in a class of twenty. However, she found that when she did not do the outreach to chemistry departments, the numbers would drop again. In contrast, every quarter without fail she gets biology students. Her hypothesis is that biology students are more attuned to seeing science in a broader context, because they study living systems. She thinks this is an area that needs more research.

LIBRARIES AND LIBRARIANS

Andrea Twiss-Brooks provided some insights on how libraries and librarians contribute to communicating chemistry and supporting informal education. She said that "after listening to all the presentations over the last day and a half, I am seeing this as a tapestry of informal learning. There are lots of threads; there are lots of different types of informal learning that take place."

Twiss-Brooks noted that librarians in the university environment have a mission to support teaching, learning, and research for all users. Science libraries try to do that across a broad range of scientific disciplines, including chemistry. In considering the special role of libraries and librarians in informal education, she said three themes emerge:

1. Providing spaces for learners and learning and for programs and activities,
2. Providing and organizing authoritative information resources (from print to electronic sources, as well as web-based resources and any other kinds of information resources that may be available), and
3. Providing other skills that librarians have developed for their own use that they can then turn into collaborative efforts with their communities.

For example, spaces include library exhibits, meeting rooms, or other learning spaces, with areas for both individuals and groups and for formal lectures, as well as less formal activities. The information librarians provide includes organizing guides, lists, and various other tools to help inform learners about how to find good-quality information, as well as the types of resources available. Librarians also often provide organizational skills and insights on assessing programs, activities, and services.

Twiss-Brooks gave a specific example of an activity done in collaboration between a faculty member at the University of Texas-Dallas and local public libraries in the Dallas region, called "Contact Science."[3] The way it works is that there is a stand-alone (self-explanatory) kiosk on a particular science topic, about the size of a tabletop, designed to fit into a public library space. Along with the kiosk, there are associated activities, projects, and mentoring for the libraries that install this in their environments (including any specialized or unusual consumables that might be used as part of the activities). The program also contributes selected books to the library that is hosting the kiosk. She encouraged workshop participants to check out the Contact Science website for more details. "This is a fairly new program, but it is a good example of the way that libraries can serve as neutral spaces for activities," Twiss-Brooks added. Kiosk locations are listed on the website.

Because universities can sometimes be political or territorial, the library often represents a kind of neutral ground, said Twiss-Brooks. It is a great place to have activities where multiple departments may be trying to collaborate to provide a program or service, and rather than having one of

[3]For more information, see *//www.utdallas.edu/seec/contact_science.html.*

the departments be the home for where the activity actually takes place, it can happen in the library which everyone kind of sees as their friend.

Libraries can also serve as a space for museum exhibits. "Public libraries are distributed around regions and in communities. So this is an excellent way for the folks that might not necessarily have easy access to a science museum to get this kind of high-quality informal learning content," Twiss-Brooks added. An example she provided was from her colleague Emily Wixson at the University of Wisconsin, Madison. Wixson does a lot of outreach work, where some of the outreach is programmatic and some is one-time events. She is especially interested in chemical information literacy, teaching people how to use the tools to discover good chemical information, for her own chemistry students as well as for nonchemists and nonspecialists. Wixson says she tries to make chemical information and the chemical literature accessible to nonscience colleagues. She does that by teaching chemical structure building with gumdrops and with marshmallows. She also took place in an edible book contest recently, where she chose to make a chemistry book *Crime Scene Chemistry for the Armchair Sleuth,*[4] which she did to make people aware that there are popular books on science and chemistry for the layperson in the library.

In addition, libraries also put on their own exhibits, highlighting permanent collections, research on the university campus, research of the local community, and other special features. Some examples of science-based library exhibits include one that the Nobel Library at Arizona State University (ASU) did on *It's a Dry Heat: Biological Adaptations for Life in the Arizona Desert*; another one ASU did was *Remote Sensing*, an exhibit highlighting current applications and research at ASU; and another one involved social insect research, which was complete with ants.

Twiss-Brooks said that she and her librarian colleagues also try to highlight resources in their libraries. For example, the University of Illinois, Urbana-Champaign, had an exhibit *From Alchemy to Chemistry, 500 Years of Rare and Interesting Books*. Another example was something she did in her own library, called *Something Brewing: The Art, Science, and Technology of Beer Brewing*. Often with these exhibits they also bring in lecturers for the opening or for a special evening, and they also try to bring in scientists. For the exhibit on beer brewing, they had a historian of breweries in Chicago that came and talked. She emphasized that they try to feature the science and technology aspect of the materials and the materials from their collection.

[4]For more information, see *http://www.library.wisc.edu/edible-book/pictures10.html* (accessed June 6, 2011).

Acquiring and Organizing Information Resources

The second topic, acquiring and organizing information resources, is something that librarians consider their core principles and core values, Twiss-Brooks said. She quoted Linton Weeks, who said in the January 13, 2001, *Washington Post:* "In the non-stop tsunami of global information, librarians provide us with floaties and teach us to swim." For example, in another example from Emily Wixson at the University of Wisconsin, Madison (Figure 7-1), Wixson was involved in an information technology academy at the University of Wisconsin, where she offered a workshop for first-year students. The original workshop she designed was called *Jellybean Chemistry*, and it looked at chemical visualization on the Internet. Twiss-Brooks said that many examples like these can also be found in public libraries.

Another example Twiss-Brooks gave was the *Sci-Tech Library Newsletter* at Stanford University, which has different themes throughout the year. It does holiday themes, such as the one she showed about Halloween and science, developed by Stephanie Bianci. Based on the comments and feedback received on the site where it is hosted at Stanford's Swain Library, they know that this site is being used by general users, home schoolers, and others who are interested in both formal and informal education.

Some other examples of guides that libraries produce involve science, with a speaker providing information on correct citation, how to use bibliographic management tools, and other such resources. Twiss-Brooks said that these topics are sometimes taught in science writing or the writing centers on campus, but they are also often handled by the library.

Libraries provide resources—purchased, licensed, and free—that they collect and organize. One example are books in the "Saturday Science Series," by Neil Downie[5] which is something that Twiss-Brooks purchased for the collection at her school and that is the library catalogue. For example, these types of resources are available to members of the university campus community, who may have children of their own whose science learning experience they are trying to enrich, as well as visitors from outside the university community who use the library.

Sharing Librarian Skills

Twiss-Brooks then discussed how librarians share their skills. However, she warned, there are limitations to what a library can do. As Lily Tomlin said, "If truth is beauty, how come no one has their hair done in a library?" She added, "I don't think I am going to be offering cosmetology or haircutting services in the library."

[5]For example, see N.A. Downie. 2001. *Vacuum Bazookas, Electric Rainbow Jelly, and 27 Other Saturday Science Projects.* Princeton: Princeton University Press.

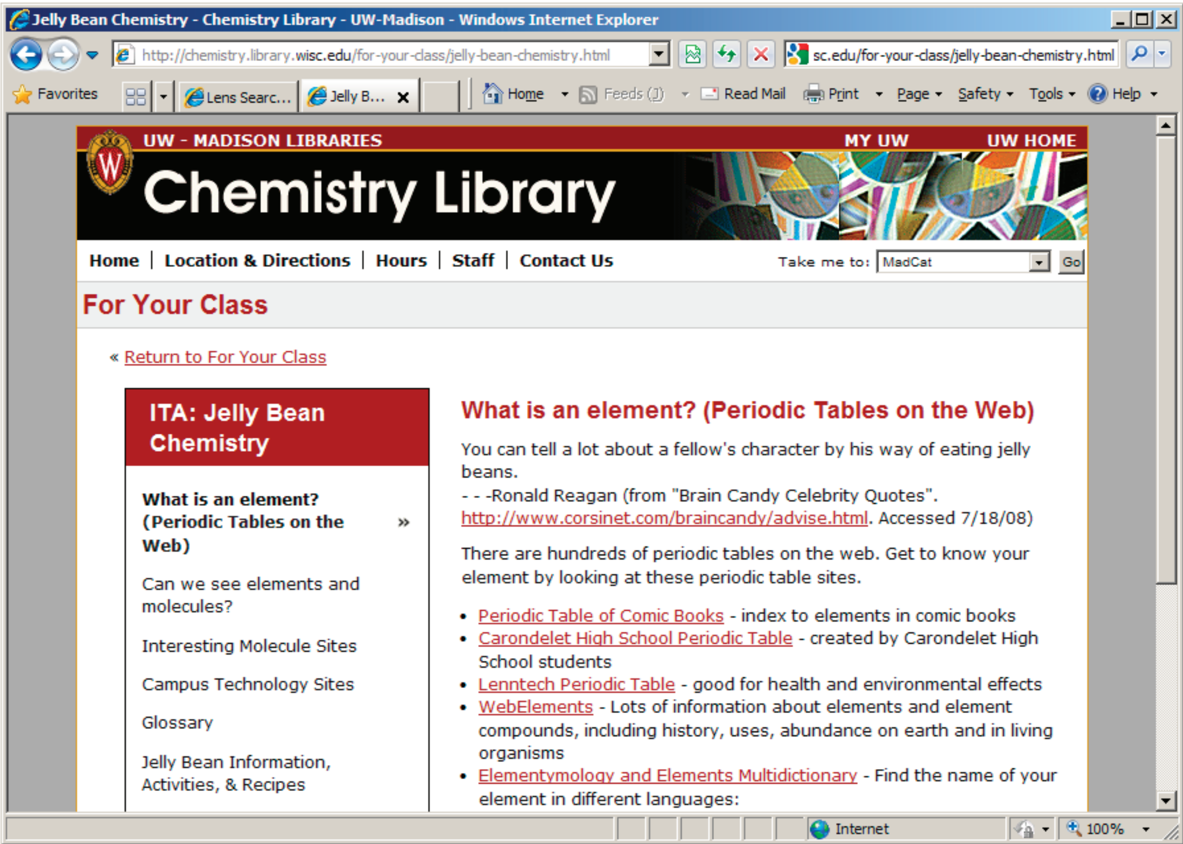


FIGURE 7-1 Acquiring and organizing resources.
SOURCE: Andrea Twiss-Brooks screen shot, *chemistry.library.wise.edu/for-your-class/jelly-bean-chemistry.hml* (accessed June 6, 2011).

Several years ago, Twiss-Brooks was asked to be involved with the American Chemical Society Committee on Community Activities. Her colleague Grace Bassinger started with the committee creating lists of resources and helping to tie the library into their outreach activities, such as National Chemistry Week (NCW) and Earth Day (Figure 7-2).

Twiss-Brooks explained that being part of the ACS, the members of the Committee on Community Activities are interested in trying to meet the organizational goals. One is to communicate with the public, especially the general public, "the nature and value of chemistry and related sciences." In the ACS strategic plan, it also states that progress toward the communication goal involves instilling a positive perception of the nature and value of chemistry by participants in ACS activities.

Librarians can also be very helpful in assessing outcomes and impacts of outreach. Twiss-Brooks described her experience with reporting requirements for the Institute of Museum and Library Studies grants program. She said librarians "are very good at counting, we can count how many people went to an event, we can count how much money we spent on the event, we can count how many volunteers we had. But how do we really look at these outcomes for these kind of one-shot events? That was what I took back to my work on the Committee on Community Activities."

To assess the impacts of NCW outreach efforts in 2009, Twiss-Brooks and the Committee on Community Activities came up with a survey for outreach participants. They tried to include some core questions that would at least try to capture whether there was an impact on attitudes toward chemistry as a result of these events, with the target audiences being elementary and middle school and some high school students. They were given a 20-question survey, to reflect on their experiences after they just spent the afternoon making "flubber" or other chemistry activities.

One of the core questions of the survey was, "Before coming to this event today, I thought that chemistry was: (choose one) bad, boring, okay, interesting, awesome." The second core question was, "After attending this event, I now think that chemistry is: (choose one) bad, boring, okay, interesting, awesome." They also collected demographic information, such as male or female, age range, whether they learned something new, and whether they would come to another event. The survey was initially piloted with five

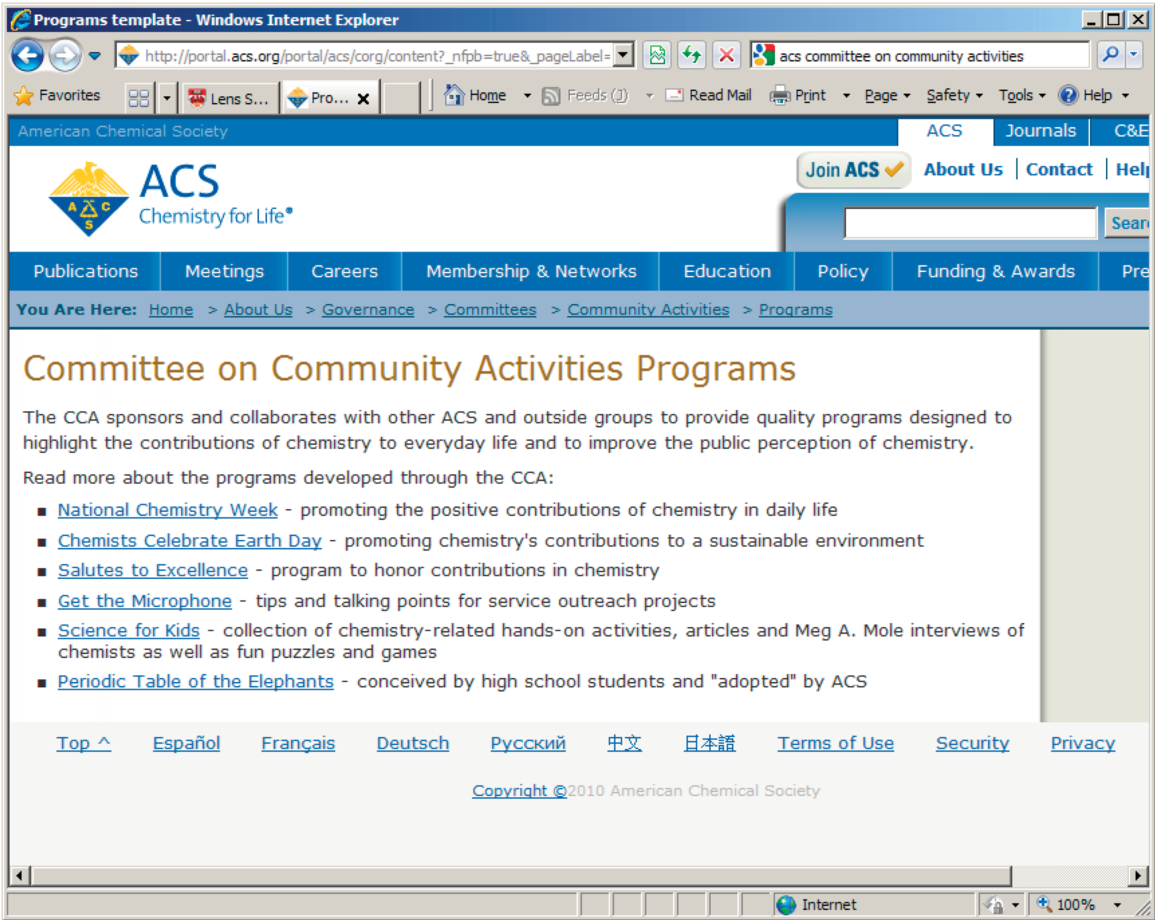


FIGURE 7-2 American Chemical Society Committee on Community Activities Programs.
SOURCE: Andrea Twiss-Brooks, web screen shot.

local sections. The survey seemed to work, and the kids seem to understand what was being asked, so the committee then expanded for the next NCW Celebration to 17 local sections, with 1,369 completed surveys.

From the survey, they found that most of the responses were from children who were attending the event, although Twiss-Brooks said they did get a significant number of responses from adults as well. However, what they found most interesting was doing a cross-tabulation of the two core questions. They looked to see if there were significant changes in the answers for before and after attending the event. She said, "We did see that of the 16 responses that said they were bad, they thought chemistry was bad before they came to this event, all but 3 changed their answers to something somewhat better. In fact, the majority of them, 12 of the 16, said it was either interesting or awesome." There were similar results with the boring and okay responses, but there were also some who responded that they were not changed by the event. Twiss-Brooks added, "We do realize that reflective questions are not perfect, but they were kind of the best we could get since we couldn't really pre-test and post-test these folks. But they did at least seem to have a positive experience and take something positive away about chemistry from these events."

The committee is continuing to look for other types of technology that may be suitable for assessing the impacts of these very informal learning activities. One of the things it is just beginning to experiment with are electronic comment boards. Twiss-Brooks showed an example of what she called "American Idol Meets National Chemistry Week," where they set up a text message board through a free source called "Text the Mob" that was advertised through the Pittsburgh local section. They did not get very many messages, but it was interesting to see what they did get, such as "I liked La Roche College's table," "I loved the gummi worms from Duquesne," or "I liked AIChE's table)." They are now looking to expand this technique, and possible others like Twitter, at the next NCW celebration, for each of the local section events to see if they can get feedback, she added.

Besides doing assessments, the kind of commentary they have collected has also proved helpful for local sections to show corporate sponsors or museums that host their events that the outreach is having an impact. It helps them to continue to secure both locations and funding for these events, Twiss-Brooks added.

OPEN DISCUSSION 6

Mark Griep, University of Nebraska, asked Bob Hone about collecting demographic data on the students who play Red Hill games, "How do you know what student is playing what game, and how can you track them?"

Hone replied that they collect basic information on players in terms of their age and gender from PBSKids. They also do parallel testing in classrooms, "so we don't rely just on online." They use something called PROS (parallel remote online system) that is like remote sensing, such as data being collected simultaneously by a satellite system and ground troops—there are evaluators who go out into classrooms and see if the classroom data and online data match.

Mike Rogers, National Institutes of Health (NIH), commented that Hone might be on to something with the games. He said, "I have a 14-year-old in middle school, and I would say the vast majority of his screen time now and that of his friends, is on his laptop, not on television. And most of the time they are playing computer games, a lot of different computer games. Some of their favorite ones are role-playing games where they have avatars and they take on challenges and earn points, and they can buy things on the game with those activities. He can actually chat with his friends while he is playing the game, so it is very engaging for him." Rogers asked, "What does it cost to make games like that? If someone wanted to make a computer game where your avatar was a chemist, for example, are we talking millions of dollars?"

Hone replied, "Let us do a couple of definitions. It is a multiplayer online game, right? You want to make sure you have enough people. Building a great game is kind of like building a great restaurant: if nobody goes in it doesn't matter how good your food is. You have to promote it, you have to get it out there. I think I would say somewhere around a quarter of your budget is going to be on the promotional side. I will be honest, we have not done a lot of multiplayer games. I am not going to try and give you a number. Could you spend millions? Sure. Could you do something for a couple of hundred thousand? Probably."

Jeannette Brown commented that "librarians are good with databases." She said there is a database called "The Faces of Chemistry," about African Americans in science that was started by a librarian who was in New Orleans at the time. Brown highlighted the value of these databases, but remarked that some databases are not accessible; in some cases you have to be a member of a library community to access them. She asked Twiss-Brooks if that can be changed.

Twiss-Brooks said that besides the licensed databases (those that you pay for), there are some very good free sources out there. Some of her colleagues have put together guides to those free or low-cost resources that are available. There are resources such as ChemSpider, which "is a collaboration of a developer with the Royal Society of Chemistry that has a great deal of free chemical information in it." In general, anyone can physically go into the library to access the databases at her library; that is, they can use the resources while they are in the library, they just cannot go home and access them remotely. She said, "We help people all the time trying to find resources that are accessible to them, or pointing them to their local public libraries to see what they have got available as well."

Steve Lyons asked Hone about the Wii board he held up at the end of his talk. He said, "I think you made a sort of fleeting reference to 3D structure. I just wonder if you could fantasize about how Wii might be used to help people in a game situation understand 3D chemical structures."

Hone imagined a game where the player is outside of a cell and has some kind of chemical that has to get rotated into a particular orientation to fit into the receptor of the cell to open the channel and let a partner's ship go through the channel, for example. He said there are many things you could imagine learning. Lyons encouraged Hone to make such a game. Hone replied, "Ask a creative director and don't give me a budget, and I can give you anything."

Bill Carroll commented to Twiss-Brooks that in listening to her presentation, it seemed that there is a coming convergence between libraries and museums in terms of content and presentation. Another example of this is the Chemical Heritage Foundation, starting as a library and morphing into a museum. He asked, "First of all, is that a correct observation? And second, can you play that out 5 years for us?"

Twiss-Brooks replied, "There are certainly collaborations between libraries and museums already. Many museums have their own libraries; in other cases libraries are working with museums, providing materials from their collections that complement the museum's collections." One other thing she mentioned is that museums also are producing traveling exhibits that are very easy for libraries to mount in their own spaces and connect with their own communities. Her library posted one from the National Library of Medicine recently on changing the face of medicine, which happened to feature a University of Chicago researcher, Janet Rowley, and then she was able to do a talk at the library based around that exhibit.

Another thing libraries are delving into is the idea of putting their exhibits online, much the same way museums are. Twiss-Brooks said, "I think we probably have expertise to learn from one another. I think museums will still have a different role perhaps than libraries and sort of packaging and presenting experiences to interested visitors. Whereas libraries at least in my field and in academic libraries are places where the researchers go to explore the raw material, so to speak, of their interest and then synthesize that for their own use. I think that there is rich potential for collaborations. I think we will both still have our own roles, but maybe there are ways that we can bring those skills together."

A participant asked Hone how accessible video game creation is at this point, "Presumably there are some tools out there for people like amateurs to make, and is that a possible avenue to make like little applets for a classroom? How accessible and how much time would be involved?"

Hone responded that the tools are available. A lot of the material for PBSKids was built in Flash. He said, "I think the harder challenge is the craft of game design. Having done television, having done instructional activities, I think game design is probably the toughest, because you are juggling not only the technical challenges of the programming, the art challenges, but also this contract of how you keep it interesting, and how you build that mountain of challenges. So I think the tools are there. I think what is probably lacking are people who are skilled in the aspects of game design."

Brown suggested to Twiss-Brooks that for the next year (2011), which is the International Year of Chemistry, the University of Chicago should do an exhibit on African-American chemists. For example, the library could pull their theses out to display and highlight the work of the pioneering students. She offered to help Twiss-Brooks find material.

Finally, Mike Rogers commented on how easy and effective it is to go to various websites and blogs and pose questions, for example, when planning a vacation. He asked Twiss-Brooks if there are such sites for people who might have questions about science or chemistry? She replied that there probably are, but she wasn't aware of any. Hone mentioned one site called "Ask An Astronomer" and thought there might be a comparable "Ask A Chemist."

8

Workshop Wrap-up Session

"Don't get caught needing a translator!"
–Nancy Blount

Four workshop participants, Joy Moore of Seed Media, David Ucko from the National Science Foundation, Nancy Blount with the American Chemical Society, and Mark Barteau at the University of Delaware were asked to provide closing comments. Chosen for their diverse perspectives, each panelist discussed what they heard during the workshop and what some next steps might be. The panel comments were followed by an open discussion period where all workshop participants were given the opportunity to respond to the panelists and raise additional issues brought up during the workshop.

BRIDGING THE COMMUNICATION GAP

Joy Moore was struck by the gap between public understanding of chemistry and the ability or inability of chemists to explain what they do. She said that the most successful examples of overcoming this gap occur when chemistry is related to things in daily life, such as a museum exhibit, and when scientists explain what they do in their own words, as is done in science blogging.

Another take-away message was the need to highlight the chemistry behind larger societal problems. There are also various ways to present information to children, such as video games, museum exhibits, and activities on the Internet, and parents may need to be made more aware of the resources for informal learning outside of school.

STRATEGIC PLANNING

David Ucko suggested that developing a strategic plan could help focus the goals for communicating chemistry. It was not clear to him if the goal is learning, public relations, advocacy, or some combination of all three. At the same time, he pointed out that this topic is not new. Efforts to expose more people to chemistry have been highlighted on several occasions in the past. For example, an American Chemical Society (ACS) Committee on Public Understanding of Chemistry wrote a report published in 1971 titled *Chemistry for Citizens*.[1] Various efforts followed. Chemist Richard Zare, as Chair of the National Science Board, wrote an article in 1996 titled "Where Is the Chemistry in Science Museums?"[2]

Chemists have been wrestling with this topic for a long time. Those who want to pursue informal educational activities in chemistry could look to the evidence base that has been gathered since those earlier efforts and the lessons that have been learned. Ucko said it would be useful for someone to do a synthesis of the lessons learned from these past efforts, such as from the research that the National Science Foundation (NSF) and others have funded on learning chemistry. He said that most of it has probably been on the formal side, but there are some valuable lessons to be learned.

TAKING CHEMISTRY TO THE STREETS

Nancy Blount, American Chemical Society, pointed out that there so many audiences to reach and all have different needs. There is also so much that is unknown about how best to reach those audiences. She heard a lot of people at the workshop speak about the challenges of getting chemistry to the forefront of people's minds, from the invisible to the visible. She said when chemistry gets to the point of being visible, it often crosses a line where it becomes the prize of

[1]For more information, see R.L. Wolfgang.1971. Chemistry for citizens. *Journal of Chemical Education* 4 (1): 22.

[2]R. Zare. 1996. Where is the Chemistry in Science Museums? *Journal of Chemical Education.* 73:A198. Available online at *http://jchemed.chem.wisc.edu/journal/issues/1996/sep/absA198.html* (accessed April 12, 2011).

another discipline, such as medicine, materials, or maybe electronics, but not chemistry.

Blount also talked about the public perception of science. While data from Pew Research suggest people respect scientists, she said they really do not understand what scientists do, or some of the most basic facts about science. She added, "Obviously there is that big disconnect that invites us to step in and do something about it."

Blount talked about the approaches needed to address this. She said efforts are needed at all levels from individuals engaging one on one, or through organizations such as ACS local sections, museums, and libraries. There are also many opportunities through media sources, including newspapers, books, movies, television, radio, the Internet, and games. However, there is a lot that is unknown about what works best—what people really relate to and what has impact.

At the most basic level though, Blount pointed out that everyone has a story to tell and plenty of opportunities to tell it—whether it's at a barbeque, a wedding, a graduation, or a family reunion. She advised, "Somebody is going to ask you what you do. Don't get caught needing a translator." Instead chemists need to be prepared to discuss the work they do and why they do it.

In addition, Blount said, "Think about this opportunity. . . . When you talk to somebody one on one you have their attention." However, when people browse websites, it is more difficult to know how much time they spend on it or what kind of message they get from it. "But when you get their attention, take advantage of it and be ready to tell them something that is going to be meaningful to them about chemistry," Blount added.

THE MESSAGE, MEDIUM, HOOK, AUDIENCE, AND MESSENGERS

Mark Barteau, University of Delaware, outlined five crosscutting themes he heard. The first is the message. He said, "I think the *message* we should be sending is we change the way people live, and go from there."

The second theme is about the *medium*. He said he came to the workshop expecting to hear a lot about new media and creative and innovative approaches, which he did. However, he heard more about how clever people will adapt quickly to these new media.

The third theme is the need for a *hook* to grab the attention of a reader, viewer, or museum visitor. Barteau worries that in the quest for relevance, the message becomes a little bland. For example, he highlighted the success of the TV show *Myth Busters* and how both kids and adults enjoy seeing things blown up on the show. At the same time, he noted that Martyn Poliakoff finds the videos of himself talking about the chemistry of a candle just as popular as the videos of him blowing things up. Poliakoff thinks those videos are more visual and exciting, hooking his audience, whereas the videos of him talking keep viewers interested. Barteau added, "We need to think about the hook and how we bait it. And again, I think there are lots of opportunities for creativity there."

The fourth theme Barteau pointed out was about tailoring the message to suit the type of *audience*. For example, it was said in the workshop that the audience for museums is already self-selected or predisposed toward science and learning, so that audience will respond to a different level of communication than that required for TV viewers.

The last theme Barteau discussed was about the *messengers*—chemical professionals. Barteau said the academic community is "waking up to the idea of the need to mentor our students and their professional careers." Funding agencies are also putting more pressure on faculty to improve how they mentor their students. However, he thinks faculty are not well equipped to do this. For them, "mentoring means how to write a proposal, how to write a scientific paper, how to give a talk at an ACS meeting." It does not typically involve how to talk to the press or a boss when there are only 5 minutes available. He added that the biggest challenge in improving communications training for scientists and engineers is finding qualified people in the universities to do it.

OPEN DISCUSSION 7

Do Chemists Need to Get Out More?

Bill Carroll highlighted something Deborah Illman discussed in her presentation earlier in the day. Most of her graduate students (in the sciences) admitted they have essentially no, or very little, contact with nonscientists on a daily basis. Carroll posed the question, "Do chemists need to get out more?" Nancy Blount responded that she was astounded by Illman's findings, and thinks students need to be motivated by their professors to think about more than just research activities.

Ucko said that the human side of science is often missing. He thinks it would be helpful to show more of the human side in both the formal and the informal science learning environments.

At the same time, there have been successes. For example, Bill Carroll noted that scienceblogs.com seems to do a good job finding articulate and funny scientists who comment online, and asked Joy Moore about where she finds them. Moore said the blogosphere draws writers to the website, and "allows people who are good communicators and who have a personality that goes along with their research to make themselves known and then gain their own audiences." This visibility shows other scientists that science blogging is okay, and the interaction between the bloggers and the readers opens up a dialogue. She added, "We know that there are cool, interesting human beings out there doing research, and we just need to get that message out to the public more."

Bill Carroll asked Mark Barteau, from his position in academia, to comment on whether there is a need for a "communications competency requirement particularly in a graduate program?"

Barteau said that as a department chair, he cannot remember an industrial advisory board meeting of his department that did not involve a discussion about the communications deficiencies of their students. He responded yes to Carroll's question, but also emphasized the need to make it fun and interesting. He said "Running [students] through a required communications or technical writing course may not be the way to go." On the other hand, his university has an NSF Integrative Graduate Education, Research, and Training program, and the students are the ones driving the outreach to the community. He said it would be useful to systematize the outreach or at least collect information about it in a way that would be valuable to others and spawn more imitation.

Bill Carroll said he thinks there is a convergence between Deborah Illman's thoughts and the ACS Chemistry Ambassador's approach. That is, it is important to get to say what is most important first, rather than burying it somewhere in the article or conversation.

Nancy Blount added that when scientists talk about their research, they tend to focus on giving all the background technical details first, which turns most nonscientists off. She reiterated, "What we all have in common is we are all people." It can be much more impactful for the scientists to start with the human side of the story—who are they? Where do they come from? How did they get interested in science and their particular area of research? "Each one of us is the human side of some story."

In today's age, however, the attention span of most people is short, so "you need to have a really short sound bite that is going to hook them and get their attention, and give them a chance to ask you more."

Overcoming Negative Stereotypes on TV

Many participants discussed their dissatisfaction with how chemists and chemistry are shown on TV. For example, Neil Gussman, from the Chemical Heritage Foundation (CHF), commented on how his daughters' views of chemistry are strongly affected by the Nickelodeon television show they watched in the late 1990s called *The Secret Life of Alex Mack* [3] which painted a very negative and unrealistic picture of chemicals and chemical industry. In the show, an unmarked truck from a chemical company spills an unnamed brown liquid on a girl in junior high named Alex Mack. The brown liquid gives Mack the ability to turn into a puddle of mercury at will. The villain of the show was a security guard at the chemical company, who spent the four years' worth of episodes of the show trying to catch Alex Mack because she was violating the security of his chemical company. Alex Mack's parents worked for the chemical company, but they were totally unaware of what was going on. Gussman said if that is the image of chemistry,[4] what can be done to dig out of that hole and overcome the negative stereotypes?

Ruth Woodall highlighted Bill Nye the Science Guy as a positive image for science in the public media. He was on CNN the previous night talking about possible solutions for cleaning up the BP oil spill.[5] She said that he was a very useful resource when she was a science teacher. Kids really enjoyed watching him. She called him her hero, because of the ability he has to connect with people of all ages.

Joy Moore responded to the comment about *Alex Mack* that the perception of industry versus academic scientists is a real problem. She said, "There is a huge, immediate distrust of scientists who work for companies, as opposed to scientists who work for academia. And it is just obviously unfair and wrong."

Jim Solyst then posed the question, "How do you take creative people who are in communications and give them the necessary guidance or education to do it a bit better than what we see on *Alex Mack*?"

Mark Barteau responded, "One of the problems is figuring out how to do that without putting them through a 4-year bachelor's degree." He said that one thing they did at Delaware recently was hold an energy workshop for the media. They discussed "key things you need to have in mind, and a few questions you ought to ask everybody, whether they are selling clean coal or wind power. Just here are the key questions you should always ask."

Steve Lyons then highlighted a couple of resources to follow up on the idea of bringing creative people (who are not chemists) in to help communicate chemistry. He said that the American Association for the Advancement of Science (AAAS) has a science-writing program for journalists and scientists. Lyons participated in a science-writing program called the Macy Fellowship in Science Broadcast Journalism. He said, "The idea was to take people who had already written about science, either articles or books, and train them in broadcasting. They brought us to Boston and trained us in radio and film and television for a year, and then sort of set us free and saw what we could do."

Lyons said, "It might be possible to develop a fellowship in chemistry communication that is similar to that—that takes creative people who have shown expertise or flair in some kind of communication field and bring them to a central

[3]For more information, see the Internet Movie Database at *http://www.imdb.com/title/tt0108921/* (accessed April 13, 2011).

[4]In this document, chemistry is defined as the science of composition, structure, and properties of substances (chemicals) and the changes they undergo.

[5]For more information, see *www.usgs.gov/oilspill/* (accessed December 2, 2010).

location and train them in how to communicate chemistry and send them out into the world."

Jim Solyst thought that was an excellent idea, and suggested that Mark Grieps's work on movies and the examples he showed in the workshop would be great resources for reaching out to screenwriters, to show them how science and chemistry can work on the screen. If screenwriters can be convinced that people are interested in subjects such as chemistry when presented in an interesting and compelling way, more movies with chemistry content might be made.

Jeannette Brown shared one idea she implemented in the past to increase coverage of chemistry in the media. She said that in her role as a publicity person for her ACS local section, she invited a reporter to attend a talk at one of the regular local section meetings for background material on a hot political topic. She has also learned ways to communicate chemistry effectively as a member of the Science Writers organization. She suggested that maybe the ACS could do a session on chemistry at the Science Writer's Conference.

Writing for Life

Deborah Illman commented that one of the things she has observed about existing communication and writing training for undergraduate chemistry students in the universities across the country is the focus on writing lab reports and term papers. She has tried to interest people in something she calls "writing for life," which involves writing for learning in informal and formal environments, such as communicating science to policy makers, journalists, the PTA, or the neighbor next door. She has not had success conveying that message though. She said, "I think that on a national scale, with a call for preparation for chemists and scientists generally to communicate with broader audiences, and a requirement of funders for grant recipients to show how they are going to do that, I think we have to mount a major national campaign to reach into the undergraduate curriculum and the graduate curriculum and provide some major resources and guidance, and to give it a priority for these kinds of communication genres in writing for life."

David Ucko responded that "I just want to remind people that this is just one piece of this huge puzzle that we are dealing with here, this tapestry or web or ecology of lifelong learning." In addition to thinking about the professional development of scientists and the professional development of media, it would be beneficial to also create regional collaborations to connect all the different pieces, so that they can support each other, provide a structure to bring in others, and reach some common outcomes.

Trish Baisden described how she recently spent 3 years in Washington, D.C., on an assignment and had to learn really quickly how to talk to people there, because they only had a short amount of time to listen. She noted that this is very different from what was expected during her scientific training. Scientists tend to focus on providing all the details and being very accurate. They are not comfortable with generalizing or leaving out important details. Sometimes at her lab they bring in technical writers to help communicate research results to general audiences. She said, "The technical writers do a great job, and then the scientists [say] yes but, and then they start adding detail. Pretty soon you take an article that was a fun 2-page article, and by the time we get all the detail that makes it absolutely correct from the scientific point of view it is 10 pages and nobody wants to read it."

Baisden asked about how to bridge the gap between the two: "How do we talk about what we do in a way that it may not be absolutely correct and have all the details, but it gets the point across, it gets the interest across?" She asked Deborah Illman, "When you got the technical writer talking to the scientists, how do you get them so the technical guy will kind of let up a little and the technical writer will give in a little, and you end up with a good product?"

Illman responded that it is helpful to sensitize scientists to the needs of broader audiences, through the types of activities she does in her course. She believes it is valuable to provide some training on communicating to broader audiences in undergraduate and graduate courses, even if it involves just a few credits. The training would be useful to the students in many settings, including outreach to museums, in the policy arena, and in industry, to management. It would be beneficial for students to be instructed in writing for life and general audiences, instead of simply learning how to write term papers.

Tolerable Level of Inaccuracy

Bob Hone commented that "science museums and the people who work in science museums interact with the public directly, so they have a really clear idea of what is going to work and what is not going to work." He said when working on a project for a science museum, they talk about what they call "the tolerable level of inaccuracy." As concepts are simplified, at some level it will end up being inaccurate to a scientist. He said it is necessary to think about the duration of the experience the person is going to have with the content. It may only be few minutes, which is not a lot of time to convey all the details.

David Ucko agreed with Hone. He emphasized that there are people who are experts in being intermediaries between the public, the science, and the scientists; that is what educators in the science museums and many other informal learning spheres do for a living. He strongly encourages scientists to interact with those people to learn from their knowledge and experience.

Cathy Conrad from St. Mary's University commented that there is a lot of interesting discussion going on about how "the medium is the message"; that the content and key ideas are influenced by the communications media such as video, radio, museums, and so forth. However, she said there is still a need to have a fundamental message, idea, or concept that is independent from the media. It was not clear to her, from the discussions at this workshop, what exactly those are for chemistry.

Nancy Blount shared some thoughts from the perspective of the American Chemical Society (ACS). She said that the ACS vision is "improving people's lives through the transforming power of chemistry."ACS tries to integrate that into a lot of its literature and speeches. ACS also emphasizes that chemists are problem solvers and that chemistry is solving global challenges. This provides a platform to talk about important topics such as climate, clean water, and sufficient food supplies.

Ucko commented that in the case of learning, the message and the approach needed may be very different. For example, it depends where the person is and what he or she is interested in. He provided a website created by the Exploratorium[6] called *The Accidental Scientist*,[7] which focuses on the science of cooking. The museum does not rely on people going to the Exploratorium to find that site, but rather on people finding it through a cooking site. The link to the website is located on many cooking sites, because people who are interested in cooking gravitate to those types of websites. Then they can find the information on the science behind the cooking if they are interested. Ucko described it as a backdoor into the science. There is not a particular message, but it is providing the science as needed when people are most interested.

Teresa Fryberger commented that she agreed with the comment about the message that "we really need to think about why we are communicating, and who we need to communicate to." Having a strategy is important, because there are so many messages to communicate and so many audiences to communicate to.

Mark Barteau stated that one of the hardest things to teach students and young faculty is how to explain research results as they seek research funding from sources such as the National Science Foundation or the Dreyfus Foundation. He said, "You don't start with: I'm doing great stuff you should give me money." Instead, they should focus on "I'm doing great stuff that is really important to something you care about, and this is what I can do and this is why you should give me money. You would be surprised at how bad we are at getting that message across," added Barteau.

Blount agreed with Barteau's remarks. She said ACS works with individuals to help them with their elevator speeches, such as working with Illman's students in the writing workshop. Students were asked to give a 90-second recap of what their work was about, a simulated radio interview. For example, a couple of the students were working on solar cells, but solar energy never came out in the interview. Instead the students focused on the details of what they were doing. She noted that a high level view needs to be given to provide a common level of understanding and connection with the other person. The students may not solve solar energy today, but the work they do may contribute towards that goal.

Jeanette Brown said that one theme of National Chemistry Week was putting a "face on chemistry." She also highlighted the importance of participating in street festivals and community events, where chemists can make that human connection. She said, "I am really going to go back now and try to get my whole executive committee to go out and spend an hour on a street fair talking to the public there and putting a face on chemistry. These are people who have children, they have families, they live in your community, et cetera—that is the chemistry ambassador program."

Steve Lyons said that he is a member of the AAAS Committee on Public Understanding of Science, and one of the topics its members have talked quite a bit about in the last couple of years is the idea that reaching out to the public is something that is actively discouraged by the scientific community and, if you try to do it, you are jeopardizing your career. He said, "I just wonder if the assembled chemists here could confirm whether that, in fact, is a problem in the chemistry community."

Nancy Blount noted that it is not completely true—for example ACS actively encourages and supports many chemists who engage in community outreach, such as National Lab Day in 2010, Earth Day, and National Chemistry Week. At National Lab Day last year (the first year it was held), 600 people identified themselves as chemists and participated in outreach.

Deborah Illman commented on the culture that discourages public communication of science. She said, "Over the years, I have had many science graduate students come to take my science writing classes, and in a hushed tone they whispered to me, 'Don't tell my adviser I am taking this class.' It is perceived as a distraction, it is perceived as a waste of an investigator's effort to be training a grad student to divert their attention to public communication of science instead of becoming the clone that goes into a strictly academic career."

"I have encountered this time and time again," Illman said. "I am reminded of a *New Yorker* cartoon that came out, I think in 1977, where two people who look like old tenants [are] sitting in what looks like Bagley Hall on my campus, the chemistry building before it was remodeled. And one of them is saying to the other, 'One of the things I will say for us, at least we never stooped to popularizing science.'" She ended, "The sentiment is alive and well at least at my university."

[6]For more information, see *www.exploratorium.edu/* (accessed January 16, 2011).

[7]For more information, see *www.exploratorium.edu/cooking/* (accessed January 16, 2011).

Steve Lyons commented: "Maybe part of the solution is to try to address changing the culture and encouraging outreach instead of discouraging it. It is perhaps something the Dreyfus Foundation or some other funder might want to support." He asked David Ucko to comment on how the National Science Foundation is encouraging change through its funding policies of this kind of outreach.

Ucko said the Communicating Research to Public Audiences program[8] that he mentioned the previous day is specifically geared toward doing that. The program provides awards to practicing scientists who have an active NSF research grant. He said it provides up to $200,000 to do some kind of activity geared to the public, such as working with a museum on an exhibit, or doing some media project. He said that it is specifically designed to communicate research to public audiences.

Ucko also said that the NSF Office of Legislative and Public Affairs holds workshops across the country for scientists, to encourage them to assess other channels—to take videos that scientists produce and other kinds of communication pieces and put them on a national stage. Ucko said NSF overall, and the Informal Science Education division in particular, work very hard on that.

Barteau commented how he and many others were brought up with the idea that the publication by press release was not appropriate. He said part of the issue today is just the pressure on faculty time to write proposals and seek research funding. Barteau also noted that the well-intentioned NSF broader-impact criterion has resulted in "forced outreach without resources assistance or accountability." Another issue is the charlatans, or the scientists who oversell their research results. He said, "It is a multidimensional problem. But in general if we could get more responsible adults communicating more effectively with appropriate support and guidance and training to do that, that would be good."

Trish Baisden agreed. She said, "We [chemists] are uncomfortable talking to the press because we are not trained, we don't have the tools. Therefore we try to avoid it at all costs. It is a distraction; it keeps us from doing things." She cautioned that sometimes talking to the press can also cause more harm than good. For example, in the 1980s there was a big announcement about the discovery of cold fusion, and the discovery turned out to be false. She said, "We announced cold fusion; only to really look stupid." This has instilled fear in doing a press release. Instead, chemists tend to want to have their results peer reviewed and in the scientific literature a while before announcing the results more broadly.

Joel Rosenberg from Lawrence Hall of Science agreed that more needs to be done to prepare future faculty to be better communicators with the public. He said, "Chemistry becomes unpalatable to so many people because it is abstract." It tends to be too focused on balancing equations rather than practical problem solving.

Rosenberg added this is not unique to chemistry though. He said, "I work in the informal [education] world mostly, and there is also a failure in the informal world to want to take on real problem solving." For example, science museums tend to avoid more controversial topics. They want to stay neutral. They will say, "Here is the black lung, we are not saying don't smoke, we are just saying look at it and make your own decision." Similarly, for chemists it seems that they want to say, "Here is a description of a problem, but we are not saying what you should do about it." He thinks that results in chemistry being blamed for the problem, instead of being part of the solution.

Patricia Thiel from Iowa State University ended the discussion on a more positive note. She has two teenage daughters in high school, who are both interested in science, and she sees the teachers in her kids' high school making a lot of effort to incorporate presentations and writing requirements into classes. She also sees her colleagues on the faculty of the university making significant efforts to do that as well. While there is certainly room for improvement, she said many educators are putting in the effort to improve the communication skills of their students.

[8]For more information, see *www.nsf.gov/funding/pgm_summ.jsp?pims_id=5362* (accessed June 6, 2011). NOTE: This program has been archived.

Appendixes

A

Select References

ARTICLES

Amato, I. 2007. Experiments of concern: Well-intentioned research, in the wrong hands, can become dangerous. *Chemical and Engineering News* 85(31):51-55.

Amato, I. 2009. Rebecca Kamen: A sculptor nurtures an elemental garden. *Chemical and Engineering News* 87(40):43-43.

Falk, J.H., and L.D. Dierking, 2010. The 95 percent solution (School is not where most Americans learn most of their science). *American Scientist* 98:486-493.

Friedman, A.J. 2010. The evolution of the science museum. *Physics Today* (October):45-51.

Halford, B. 2008. Stephen Lyons: A television producer's take on what makes good chemistry for the small screen. *Chemical and Engineering News* 86(39):41.

Maltese, A.V., and R.H. Tai. 2010. Eyeballs in the fridge: Sources of early interest in science. *International Journal of Science Education* 32(5):669-685.

BOOKS

Ball, P. 1999. *H_2O: A Biography of Water*. London: Weidenfeld & Nicolson Ltd.

Bradley, C.A. 2009. *The Sweetness at the Bottom of the Pie*. New York: Delacorte Press.

Emsley, J. 2008. *Molecules of Murder: Criminal Molecules and Classic Cases*. London: Royal Society of Chemistry.

Frankel, F., and G. M. Whitesides. 2009. *No Small Matter: Science on the Nanoscale.* Cambridge: Harvard University Press.

Griep, M., and M. Mikasen. 2009. *ReAction! Chemistry in the Movies.* New York: Oxford University Press.

Levi, P., R. Rosentha, and N. Ascherson. 1995. *The Periodic Table.* London: D. Campbell.

Sacks, O.W. 2001. *Uncle Tungsten: Memories of a Chemical Boyhood*. New York: Alfred A. Knopf.

Stephenson, N. 1995. *The Diamond Age: Or, a Young Lady's Illustrated Primer*. New York: Bantam Dell.

NRC PUBLICATIONS

Philip Bell, Bruce Lewenstein, Andrew W. Shouse, and Michael A. Feder, Editors, Committee on Learning Science in Informal Environments, National Research Council. 2009. *Learning Science in Informal Environments*. Washington, DC: National Academies Press.

Marilyn Fenichel and Heidi A. Schweingruber, National Research Council. 2010. *Surrounded by Science*. Washington, DC: National Academies Press.

WEBSITES

Chemical Heritage Foundation	www.chemheritage.org
Community Based Environmental Monitoring Network	www.envnetwork.smu.ca/
Exploratorium	www.exploratorium.edu/
Felice Frankel	www.felicefrankel.com/
Forgotten Genius	www.pbs.org/wgbh/nova/julian/
Theodore Gray	www.theodoregray.com/
The History Makers	www.thehistorymakers.com/
Roald Hoffman	www.roaldhoffmann.com/
Informal Science	www.informalscience.org
International Year of Chemistry 2011	www.chemistry2011.org
Molecularium	www.moleculestothemax.com/
Marvelous Molecules	www.nyhallsci.org/marvelousmolecules/
Nanoscale Informal Science Education	www.nisenet.org/
Periodic Table of Videos	www.periodicvideos.com/
Science and Entertainment Exchange	www.scienceandentertainmentexchange.org/
Science Cafés	www.sciencecafes.org/
Science Cheerleader	www.sciencecheerleader.com/
Science is Fun	www.scifun.org/
World Water Monitoring Day	www.worldwatermonitoringday.org/

B

Workshop Agenda

The National Academy of Sciences Building
Lecture Room
2100 C Street, N.W.
Washington, D.C.

AGENDA

WEDNESDAY, May 26, 2010

8:00 a.m. **Welcome**
Bill Carroll and Mark Cardillo

8:15 a.m. **Introduction to Informal Learning**
Chair, Mark Cardillo
Kirsten Ellenbogen, *Science Museum of Minnesota*

9:15 a.m. **Panel 1: Informal Chemistry**
Chair, Mark Cardillo
David Ucko, *National Science Foundation*
Stephen Lyons, *Moreno-Lyons Productions*

10:30 a.m. **Break**

10:45 a.m. **Panel 2: Chemistry in Print**
Chair, Mike Rogers
John Emsley (via webcast), *University of Cambridge*
Ivan Amato, *Pew Charitable Trusts*
Joy Moore, *Seed Media Group*

12:00 a.m. **Lunch**

1:00 p.m. **Panel 3: Local Outreach Efforts**
Chair, Bill Carroll
Jeannette Brown, *New Jersey American Chemical Society (ACS) Local Section*
Ruth Woodall, *Nashville ACS Local Section*
Catherine Conrad, *St. Mary's University*

2:15 p.m.	**Panel 4: Chemistry in Museums** *Chair, Mark Barteau* Sapna Batish and Erika Shugart, *Koshland Science Museum* Susanne Rehn (via webcast), *Deutsches Museum* Shelley Geehr, *Chemical Heritage Foundation* Peter Yancone, *Maryland Science Center*
3:40 p.m.	**Break**
3:55 p.m.	**Open Discussion** *Chair, Bill Carroll*
5:00 p.m.	**Interactive Media "Poster" Session**
7:00 p.m.	**Adjourn**

THURSDAY, May 27, 2010

8:00 a.m.	**Panel 5: Chemistry in Video and on the Radio** *Chair, Sharon Haynie* Martyn Poliakoff (via webcast), *University of Nottingham* Jorge Salazar, *EarthSky Communications* Mark Griep, *University of Nebraska-Lincoln*
9:15 a.m.	**Panel 6: Tools and Techniques** *Chair, Jim Solyst* Robert Hone, *Red Hill Studios* Deborah Illman (via webcast), *University of Washington* Andrea Twiss-Brooks, *University of Chicago*
10:30 a.m.	**Wrap-up Panel** *Chair, Bill Carroll* David Ucko, *National Science Foundation* Nancy Blount, *American Chemical Society* Joy Moore, *Seed Media Group* Mark Barteau, *University of Delaware*
12:00 p.m.	**Adjourn**

C

Biographies

WORKSHOP ORGANIZERS

Mark J. Cardillo is the executive director of the Camille and Henry Dreyfus Foundation. Dr. Cardillo received his bachelor of science degree from Stevens Institute of Technology in 1964 and his Ph.D. degree in chemistry from Cornell University in 1970. He was a research associate at Brown University, a CNR Research Scientist at the University of Genoa, and a PRF research fellow in the Mechanical Engineering Department at the Massachusetts Institute of Technology. In 1975, Dr. Cardillo joined Bell Laboratories as a member of the technical staff in the Surface Physics Department. He was appointed head of the Chemical Physics Research Department in 1981 and subsequently named head of the Photonics Materials Research Department. Most recently, he held the position of director of Broad Band Access Research. Dr. Cardillo is a fellow of the American Physical Society. He has been the Phillips lecturer at Haverford College and a Langmuir lecturer of the American Chemical Society (ACS). He received the Medard Welch Award of the American Vacuum Society in 1987, the Innovations in Real Materials Award in 1998, and the Pel Associates Award in Applied Polymer Chemistry in 2000.

William F. Carroll is vice president of chlorovinyl issues at Occidental Chemical Corporation in Dallas, Texas, and an adjunct industrial professor of chemistry at Indiana University. He served as ACS president in 2005 and as a member of the ACS Board of Directors from 2004 to 2006. He is the former chair of the International Activities Committee at ACS. He earned a B.A. from DePauw, an M.S. from Tulane University (1975), and a Ph.D. from Indiana University (1978). Carroll has been an ACS member since 1974 and has served on a number of committees. He holds memberships in the Society of Plastics Engineers; American Association for the Advancement of Science; National Organization for the Professional Advancement of Black Chemists and Chemical Engineers; and National Fire Protection Association; he was the recipient of the Vinyl Institute Roy T. Gottesman Leadership Award in 2000.

Michael E. Rogers is the director of the Division of Pharmacology, Physiology, and Biological Chemistry at the National Institute of General Medical Sciences (NIGMS). He received a B.S. from Berry College and a Ph.D. in medicinal chemistry from the University of Mississippi. Dr. Rogers' research interests are in pharmacology and medicinal chemistry.

James M. Solyst is principal consultant with ENVIRON; he has more than 25 years of experience advising businesses and policy leaders on the application of science in decision making and communicating science to key audiences, including regulatory and legislative bodies. His knowledge of risk analysis and management and communication, combined with experience in national, state, and international regulatory processes, allows him to provide services at a strategic level to industry and government executives. Mr. Solyst is experienced in product stewardship, global chemical management, emergency response, and corporate responsibility. He has assisted U.S. governors with initiatives and incidents through the National Governors' Association and chemical companies responding to emerging science through the American Chemistry Council. He also has experience working on international initiatives including REACH and the United Nations Environment Programme's (UNEP's) Strategic Approach to International Chemicals Management (SAICM) and harmonization of global product stewardship programs. Mr. Solyst is a member of the ACS Committee on Environmental Improvement and an external affiliate of the Johns Hopkins School of Public Health, Risk Sciences and Public Policy Institute. He received his M.S. in city and regional planning from Ohio State University and his B.A. from the University of Maryland.

WORKSHOP SPEAKERS

Ivan Amato has been writing, editing, and otherwise engaged in acts of communication about the great and ongoing story of science and technology since the mid-1980s. He has been one of the proud and few science communicators who has specialized in chemistry. He has worked primarily in print media, but also has dabbled in radio and TV. Amato has worked on magazine staffs (*Science News*, *Science*, and *Chemical & Engineering News*), as a writer, editor, or both. For much of his career, he has worked independently as a freelancer, placing stories in newspapers and magazines, among them the *Washington Post, Baltimore Sun, International Herald Tribune, Time, Science, Fortune, U.S. News and World Report, Scientific American, Technology Review,* and *Discover*. He has done some government work too, the last instance with the President's Council of Advisors on Science and Technology. He has written several books, including *Stuff: The Materials the World Is Made*, a 1997 *New York Times* Notable Book; *Pushing the Horizon*, an institutional history of the Naval Research Laboratory; and *Super Vision: A New View of Nature*, a celebration of science imagery. He has received several awards for his writing, including the Grady-Stack award administered by the American Chemical Society and the Foresight Prize for writing on nanotechnology. Two of his articles have been listed in the Best American Science and Nature Writing book series. Most recently, Amato joined the Pew Charitable Trusts in its many-faceted approach to further the public good. For his particular part, he is using his skill set in communications to leverage the work of the Pew Health Group to be as consequential as possible. He lives with his wife, children's book writer Mary Amato, and his two teenage sons.

Jeannette Elizabeth Brown is a former faculty associate in the Department of Pre-College Programs at the New Jersey Institute of Technology (NJIT). She held the title of New Jersey Statewide Systemic Initiative (NJSSI) regional director having served as the NJIT NJSSI coordinator previously. In this position she designed, developed, and coordinated the NJIT NJSSI K-8 Professional Development Program. Ms. Brown is a fellow (Cohort 3) of the WestEd National Academy for Science and Mathematics Leadership. She is the Chemical Heritage Foundation 2004 Société fellow.

Brown previously held the position of research chemist and worked at Merck & Co. Inc. for 25 years in that capacity. She synthesized new compounds for testing as potential new drug candidates for human and animal health. She suggested new targets for development. At Merck she became coauthor of 15 publications and 5 patents, and she has one patent in her name alone. She earned a Management Award for her work with the Merck Black University Liaison Committee in which she worked with Grambling University to try to improve the chemistry department. Brown started her industrial career at CIBA Pharmaceutical Co. as a junior chemist and worked there for 11 years. She has a research M.S. degree from the University of Minnesota and a B.S. degree in chemistry from Hunter College. She was elected to the Hunter College Hall of Fame for her work as a mentor for young students.

Catherine Conrad is an associate professor and chair of the Department of Geography at Saint Mary's University in Halifax, Nova Scotia, and the founder and research coordinator of the Community-Based Environmental Monitoring Network (www.envnetwork.smu.ca). She has both local and international experience in community-based research (internationally through Canadian International Development Agency projects in Cuba, Ghana, The Gambia, and Vietnam), as well as numerous projects within Canada. Her research spans both science and social science, primarily with the engagement of communities and environmental organizations in the collection of citizen science and community mapping. This involves the collection of information on terrestrial, marine, and freshwater ecosystems, but it is driven from the needs of community organizations. More recently she has initiated a new research project involving perceptions of climate change in sub-Saharan Africa.

Kirsten Ellenbogen is senior director of lifelong learning at the Science Museum of Minnesota (SMM). In this position, Dr. Ellenbogen oversees evaluation and research, adult programs, family and youth programs, school outreach, and field trips. As a Noyce Leadership fellow (2010-2011), she is leading SMM's efforts to identify the needs of policy makers and create appropriate protocols for using the museum's resources to help policy makers better use scientific evidence to inform their decisions. She is also president of the Visitor Studies Association, an international network of professionals committed to understanding and enhancing visitor experience in informal learning settings through research, evaluation, and dialogue.

Dr. Ellenbogen started working in science centers in 1987, and she has been a demonstrator, hall interpreter, exhibit developer, evaluator, and researcher in U.S. and U.K. museums. Her leadership activities include service to the field as a founding officer of the Informal Learning Environments Research SIG-American Education Research Association, senior chair of the Informal Science Education Strand-National Association for Research in Science Teaching, and training coordinator of the Visitor Studies Group (U.K.). Kirsten was an affiliated researcher of the Museum Learning Collaborative, project director at the Center for Informal Learning & Schools, King's College London at its inception, and a senior associate at the Institute for Learning Innovation. She holds a Ph.D. in science education from Vanderbilt University and a B.A. from the University of Chicago. In addition to authoring more than three dozen publications, she was appointed to the National Academy of Sciences' committee that produced the volume *Learning Science in Informal Environments*.

John Emsley is science writer in residence and lecturer at the University of Cambridge. Dr. Emsley began his career as an active researcher in chemistry at the University of London after receiving his degree from the University of Manchester. In addition to his work as a lecturer and researcher, Dr. Emsley has been a freelance writer of popular science for newspapers, broadcast, and books for many years. In 1997, he became science writer in residence at Imperial College, London, later moving to the University of Cambridge. As a freelance journalist, he wrote a column entitled "Molecule of the Month" for the *Independent* for 6 years. In 1995, Dr. Emsley received the Rhône-Poulenc Science Book Prize for his 1994 volume *The Consumer's Good Chemical Guide: Separating Facts from Fiction About Everyday Products* (Corgi Books). In 2003, he was awarded the German Chemical Society's Writer's Award (Preis der Gesellschaft Deutscher Chemiker für Schriftsteller). His works include *Molecules of Murder; Better Looking, Better Living, Better Loving;* and *Elements of Murder.*

Shelley Geehr, director of the Roy Eddleman Institute, Chemical Heritage Foundation (CHF) leads CHF's public outreach efforts, including museum and educational programming and outreach to the general public. She also directs the work of the web, magazine, podcast, and education staff. She managed the public relations, marketing, and outreach efforts to launch CHF's museum in 2008 and is currently overseeing an extensive website redesign made necessary by CHF's expanded public presence.

Before joining CHF, Ms. Geehr worked for a variety of nonprofit educational and association organizations. She received her B.A. from Muhlenberg College.

Mark Griep is a chemistry professor at the University of Nebraska-Lincoln. He studies bacterial DNA replication and recently received a College Distinguished Teaching Award. He is the author with Marjorie Mikasen of *ReAction! Chemistry in the Movies*, published by Oxford University Press in 2009. Mikasen is a geometric painter who recently received an Individual Artist's Fellowship from the Nebraska Arts Council. The authors are married and were awarded an Alfred P. Sloan Foundation grant in the area of public understanding of science to do the research for this book.

Robert Hone is creative director and president, Red Hill Studios. In this capacity, Bob oversees the production and development activities of the company's portfolio of educational games, health games, and museum exhibitions. He is currently the principal investigator of four grants totaling $2.2 million from the National Science Foundation (NSF) and the National Institutes of Health (NIH) to develop serious games for education and health.

He received B.S. and M.S. degrees from the Massachusetts Institute of technology (MIT) in 1980 in the field of chemical engineering, after which he worked for 3 years as an R&D engineer for DuPont. He moved into the field of science journalism to pursue an interest in communicating science topics to the general public. After receiving a master's in journalism from the University of California, Berkeley, he joined the documentary staff at KQED and received the American Association for the Advancement of Science (AAAS)-Westinghouse award in 1987 for his series of documentaries shorts on science, medicine, and health: Science Notes. In 1989, he joined the science production unit at WGBH in Boston to serve as one of the Producers on the acclaimed and award-winning PBS-BBC television series about the history of the computer, The Machine That Changed the World.

He returned to the San Francisco Bay area in 1991 to start Red Hill Studios. Over the past 19 years, Bob has won nearly every award possible in the field of educational software including a Codie, the Prix Mobius award, a Muse Award, several Cine Golden Eagles, Communication Arts, numerous Invision Awards, and several National Education Media Network awards. His design efforts span large-scale (5,000 square feet) museum exhibitions, international documentary television specials, educational CD-ROMs, online educational tutorials for major publishers, and educational online games. His current energy focuses on the integration of consumer videogame design approaches with educational and health games.

In addition to producing many award-winning educational multimedia projects, he has also written several books on digital video editing. He is working on a book about educational and health game design called *Games that Matter*. He was one of the founders of the renowned Multimedia Studies Program at San Francisco State University.

Deborah Illman is a lecturer in the Department of Communications at the University of Washington (UW). Her recent research and teaching activities at UW have focused on science communication and media coverage of science and technology. She teaches a set of three courses for undergraduate and graduate students on writing about science for general audiences, as well as a course on scientific writing for graduate students. Recently, she received an NSF Professional Development Fellowship to study mental models of audiences and decision making in science and technology communication.

Illman directs the Chemistry Communication Leadership Institute, a project funded by NSF with sponsorship from the American Chemical Society. The goal is to cultivate a cadre of chemistry communication leaders who can help bring about a cultural change to promote public communication of chemistry and to mentor others now in the pipeline to be tomorrow's chemistry communicators.

During 2006-2009, with funding from a Discovery Corps Senior Fellowship of the NSF Chemistry Division, she worked on a project entitled "Team Science," focused on communicating about large and long-term multidisciplinary research efforts using the NSF Science and Technology Centers as a case study. She organized and chaired a symposium at the AAAS 2007 annual meeting on the subject of team science.

Illman is former associate editor of *Chemical & Engineering News*, the official news publication of the American Chemical Society. Based first at the Washington, D.C., headquarters and then serving as head of the magazine's West Coast bureau, Illman covered topics in analytical, environmental, and industrial process chemistry in addition to anchoring chemical education.

Illman is founding editor of *Northwest Science & Technology* (*NWS&T*; www.nwst.org). Honored with 10 awards, including 3 Best of Show awards from the Society for Technical Communication, *NWS&T* has served as an outreach vehicle, as a research laboratory, and as a platform for an experiential curriculum she developed in science and technology news and nonfiction writing at the UW. Graduates of the UW science writing program have obtained placements at national publications, including *Science*, *Discover, IEEE Spectrum, Dallas Morning News,* the *Chicago Tribune*, and the *Boston Globe.*

Her professional preparation includes a B.S. in chemistry from the University of Washington and a doctorate in physical chemistry from the State University of Campinas, Brazil. Illman is former associate director of the Center for Process Analytical Chemistry (CPAC), established with a grant from the NSF Industry-University Cooperative Research Center Program and aimed at developing new sensors for in situ analysis and online monitoring and control of chemical processes. During 1988-1989, she served as a science, engineering, and diplomacy fellow of AAAS, conducting an evaluation study of an international research grant program.

Stephen Lyons is an award-winning writer and producer with 30 years of experience in print and broadcast media. Over the last decade, he has written grant proposals and film treatments that have helped raise some $25 million for a half-dozen PBS series and specials for NOVA and *American Experience.* From April 1996 to June 2000, Lyons served as senior editor for program development at the WGBH Science Unit. There he helped launch new PBS series and specials on evolution, particle physics, the Human Genome Project, architecture, and ancient technology, as well as a series of scientific biographies for NOVA. He also co-wrote and co-produced two NOVA programs.

Lyons later served as project director of the Percy Julian Biography Project, a 4-year effort to increase public awareness of the twentieth century African-American chemist Percy Julian. The project culminated in a 2-hour biography of Julian, written and produced by Lyons and director Llew Smith. *Forgotten Genius* premiered on NOVA in 2007 and won an Emmy Award, the AAAS Science Journalism Award, and the National Association of Science Writers "Science in Society" Award. Lyons is currently developing, with support from the National Science Foundation, another chemistry project called *The Mystery of Matter: Search for the Elements,* a 2-hour special about the remarkable human story behind the Periodic Table.

Joy Moore is vice president, Global Partnerships for Seed Technology, where she works with organizations, interest groups, and individuals to define and implement technical resources that serve the interests of scientists around the world.

Before coming to Seed Media Group, Ms. Moore was a publisher at Nature Publishing Group, working with leading scientific and medical societies to extend their publishing programs. She also led the launch of the Nature Network Boston site. She received a B.A. in English literature from the College of William and Mary, but very quickly turned her interests toward scientists and scientific communication through her first job as managing editor for the *Journal of Investigative Dermatology*. She also held a number of journal and website development and management positions with Blackwell Publishing.

Ms. Moore lives by the sea in Marblehead, Massachusetts, and heads up Seed Media Group's newest office in Cambridge, Massachusetts.

Martyn Poliakoff began his academic career as an undergraduate at King's College, Cambridge, obtaining his B.A. (1969) and Ph.D. (1973) under the supervision of J. J. Turner, FRS, on the matrix isolation of large molecules. In 1972, he was appointed as a 1972-1979 research officer in the Department of Inorganic Chemistry of the University of Newcastle upon Tyne. Promotion to senior research officer followed in 1973 and led to a tenured position in 1975. In 1979, he was appointed to a lectureship in the Department of Chemistry at the University of Nottingham. Promotion to reader in inorganic chemistry and then to professor of chemistry followed in 1985 and 1991, respectively. In addition to his chair in Nottingham, Professor Poliakoff is an honorary professor of chemistry at Moscow State University. He was elected fellow of the Royal Society (2002), of the RSC (2002), and of the Institute of Chemical Engineers (IChemE) (2004) and was awarded a CBE for Services to Sciences in the 2007-

2008 New Year Honours. In 2008, he was elected honorary member of the Chemical Society of Ethiopia, and in 2009, he became adviser to the Governors of the Green Chemistry Institute of the ACS.

Susanne Rehn joined the staff of the Deutsches Museum in 2005 as the curator for the chemistry exhibition. Her major project is the redesign of that exhibition, with the reopening scheduled for 2012.

Before moving to the Deutsches Museum, she led one of the R&D laboratories at Boehme KG in Geretsried, Bavaria, a company specializing in producing chemicals for textile and leather processing, for 4 years.

Dr. Rehn completed her Ph.D. in organic chemistry in 2001. As member of the workgroup of Prof. H. Mayr at the Ludwig-Maximilians-Universität (LMU Munich), she wrote about ene-reactions of iminium salts. Prior to her Ph.D. work, she studied chemistry at LMU Munich, completing her diploma thesis in 1996.

Susanne Rehn was born 1971 in Munich; she was raised and went to school in the beautiful countryside of upper Bavaria. She is married and has two sons.

Jorge Salazar is lead producer and on-air host for EarthSky: A Clear Voice for Science. Jorge has conducted more than a thousand in-depth interviews with scientists in the process of creating science content for EarthSky. He is EarthSky's lead producer and one of a team of on-air hosts for the 90-second EarthSky and 8-minute EarthSky Clear Voices for Science podcasts. He also serves on EarthSky's Editorial Board, for both English and Spanish content for the sister program "Cielo y Tierra: la clara voz de la ciencia." These boards are responsible for choosing which scientists to interview, and the interviews form the core of the more than 20 EarthSky science podcasts released every Monday to more than 1,800 broadcast outlets and heard on a variety of online platforms each week including iTunes and Odeo. Jorge has a B.A. in physics from the University of Texas at Austin. He has interviewed leading scientists and experts on subjects as diverse as chemistry, energy, nanotechnology, satellite research, climate change, global health, population, science and policy, astrophysics, and sustainability.

Andrea Twiss-Brooks is co-director, Science Libraries Division, at the University of Chicago Library. She received a B.S. in chemistry from Texas Christian University, an M.S. in chemistry from Cornell University, and an M.S. in library science from the University of North Texas. At the University of Chicago, Andrea has oversight for building library collections to support research, study, and teaching in science, medicine, and technology. A member of the American Chemical Society, she is currently serving as co-chair of the Evaluation & Technology Subcommittee of the Joint Board-Council Committee on Community Activities. The subcommittee is working to identify and deploy tools and technology for promotion and assessment of local National Chemistry Week and Chemists Celebrate Earth Day community-based activities. Andrea is also active in support of scientific information literacy and education, including several years as feature editor for the "Chemical Information Instructor" column of the *Journal of Chemical Education*; participation in a collaborative effort to create XCITR, a repository of chemical information instructional materials; and coeditor of the geology section of Resources for College Libraries.

David A. Ucko is division director (acting) for the Division of Research on Learning in Formal and Informal Settings at the National Science Foundation, where he had served as deputy division director, section head for science literacy, and program director for informal science education. Formerly, he was executive director of the Koshland Science Museum at the National Academy of Sciences; founding president of Science City at Union Station; president of the Kansas City Museum; chief deputy director of the California Museum of Science & Industry in Los Angeles; and vice president for programs at the Museum of Science & Industry in Chicago. Ucko was a Presidential appointee confirmed by the Senate to the National Museum Services Board. He has chaired the Advocacy and Publications Committees of the Association of Science-Technology Centers. He wrote two college chemistry textbooks while on the faculty of Antioch College in Ohio and the City University of New York. Ucko is a fellow of the American Association for the Advancement of Science and a Woodrow Wilson fellow. He received his Ph.D. in inorganic chemistry from MIT and B.A. in chemistry from Columbia.

Ruth Woodall serves as the director of the Tennessee Scholars Program, a rewards and recognition program that encourages students to take more rigorous courses so they will graduate high school better prepared for postsecondary education. She was hired by the Tennessee Chamber of Commerce and Industry to start this program in 2003. Prior to joining the Tennessee Chamber, Woodall taught chemistry in the Tennessee Public School system for 20 years, serving in four different school systems. After retirement from teaching, her passion for children helped her to be able to start the Tennessee Scholars Program, which has already encouraged more than 20,000 students to graduated better prepared for success after high school. Ruth Woodall graduated from Union University in Jackson, Tennessee, with a B.S. degree in chemistry. She was named Alumni of the Year in 2004 from the Chemistry Department. In 1984 she received her master's degree in science education from the University of Memphis. Ruth has continued to earn graduate hours in chemistry, business management, public relations, and education.

Ms. Woodall not only advocates volunteerism to her students in the Tennessee Scholars Program, she is a volunteer herself in many community programs. Presently, she holds the office of councilor for the Nashville Section of the American Chemical Society. In her 19 years as an ACS member she has served as chair of the Nashville Section, public relations chair for two local sections (Memphis and Nashville), NCW coordinator for 19 years, government relations chair, Earth Day coordinator, membership chair, and strategic planning chair. She has served the National ACS for 16 years on the Committee on Community Activities and for 6 years on the Committee on Public Relations. She served as a volunteer mentor to help other start public relations committees. She is currently the chair of the Tennessee Government Affairs Committee of the ACS, the general chair for the 2010 National Science Teachers Association (NSTA) regional meeting, the past chair of the Tennessee Science Teachers Association, past chair of the NSTA Life Members Advisory Council, member of the Tennessee ACT Policy Council, member of the Tennessee STEM Council, member of the Board of Directors of the Neurological Sciences Foundation, and member of the Alignment College Access Committee.

In the 19 years that Ms. Woodall has been a member of the ACS, she has been a volunteer as a public relations chair, NCW, Kids & Chemistry, tour speaker, and community organizer of chemistry events and is now a "chemistry ambassador." She has given more than 100 professional development workshops on chemistry topics to various audiences from K-12 to the general public to counselors to legislators. She has written several articles for the news media and for "In Chemistry."

Ms. Woodall has conducted more than 500 public speaking engagements in her career. In her position as director of Tennessee Scholars she speak to audiences at schools, conferences, community meetings, and the legislature, and to small and large venues in county, state, and national. Ruth has spoken on subjects of education, science, chemistry, physics, and workforce development.

Pete Yancone is science director of education at the Maryland Science Center (MSC). Leaving the Johns Hopkins University armed with an undergraduate degree in earth and planetary science and a secondary teaching certification for earth sciences and chemistry, Pete Yancone taught middle school earth and physical science in the Baltimore City Public School System in 1976, the same year the Maryland Science Center opened at its current location. The lure of indulging a curiosity about learning, along with a high regard for informal education at the new museum, proved irresistible and led to series of positions working in all phases of Science Center operations. Almost 35 years after joining the MSC team, now as senior director of education, the staff he leads provides the outreach, exhibit facilitation, and program development for the museum.

D

Workshop Attendees

Ivan Amato
Communications
Pew Health Group
The Pew Charitable Trusts
Washington, DC
E-mail: iamato@pewtrusts.org

Trish A. Baisden
Lawrence Livermore National Laboratory
Livermore, CA
E-mail: baisden@llnl.gov

Kate Bannan
Office of Science
U.S. Department of Energy
Germantown, MD
E-mail: Kate.Bannan@science.doe.gov

Paul Barbara
Department of Chemistry and Biochemistry
University of Texas
Austin, TX

Mark A. Barteau
Department of Chemical Engineering
University of Delaware
Newark, DE
E-mail: barteau@udel.edu

Sapna Batish
Exhibits and Programs
Marian Koshland Science Museum
National Academy of Sciences
Washington, DC
E-mail: sbatish@nas.edu

Michael R. Berman
Air Force Office of Scientific Research
Arlington, VA
E-mail: michael.berman@afosr.af.mil

Nancy Blount
Society Programs
American Chemical Society
Washington, DC
E-mail: n_blount@acs.org

Jeannette Brown
North Jersey ACS Publicity Chair
E-mail: jebrown@infionline.net

Paul F. Bryan
Chevron Technology Ventures LLC
Richmond, CA
E-mail: Paul.bryan@chevron.com

Mark J. Cardillo
Camille and Henry Dreyfus Foundation
New York, NY
E-mail: mcardillo@dreyfus.org

William F. Carroll, Jr.
Occidental Chemical Corporation
Dallas, TX
E-mail: bill_carroll@oxy.com

Marvin H. Caruthers
Department of Chemistry and Biochemistry
University of Colorado
Boulder, CO
E-mail: marvin.caruthers@colorado.edu

Hattie Carwell
Museum of African American Technology Science Village
Oakland, CA
E-mail: hattie.carwell@att.net

Robert Celotta
National Institutes of Standard and Technology
Gaithersburg, MD
E-mail: robert.celotta@nist.gov

Lali Chatterjee
Communications and Public Affairs
Office of Science
U.S. Department of Energy
E-mail: Lali.Chatterjee@science.doe.gov

John C. Chen
Department of Chemical Engineering
Iacocca Hall, Lehigh University
Bethlehem, PA
E-mail: jcc0@lehigh.edu

Catherine Conrad
Department of Geography
Saint Mary's University
Halifax, Canada
E-mail: cconrad@smu.ca

Jennifer S. Curtis
University of Florida
Gainesville, FL
E-mail: jcurtis@che.ufl.edu

Luis Echegoyen
Chemistry Division
National Science Foundation
Arlington, VA
E-mail: echegoyen@nsf.gov

Kirsten Ellenbogen
Evaluation and Research in Learning Science Museum of Minnesota
St. Paul, MN
E-mail: kellenbogen@smm.org

John Emsley
Writer, broadcaster, and author
Department of Chemistry
University of Cambridge
Cambridge
E-mail: JohnEmsley38@aol.com

Teresa Fryberger
National Aeronautics and Space Administration
Earth Sciences Division
Washington, DC
E-mail: teresa.fryberger@nasa.gov

Emma Garden
Saint Mary's University
Nova Scotia, Canada

Shelley Geehr
Roy Eddleman Institute
Chemical Heritage Foundation
Philadelphia, PA
E-mail: ShelleyG@chemheritage.org

Mark A. Griep
Department of Chemistry
University of Nebraska-Lincoln
E-mail: mgriep1@unl.edu

Neil Gussman
Strategic Communications and Media Relations
Chemical Heritage Foundation
Philadelphia, PA
E-mail: NeilG@chemheritage.org

Sharon Haynie
E. I. duPont de Nemours & Company
Central Research & Development
Wilmington, DE
E-mail: sharon.l.haynie@usa.dupont.com

Bob Hone
Red Hill Studios
San Rafael, CA
E-mail: bobh@redhillstudios.com

Deborah Illman
University of Washington
Seattle, WA
E-mail: illman@u.washington.edu

Stacy Kish
Office of Science
Department of Energy
Washington, DC
E-mail: Stacy.Kish@science.doe.gov

John Kotcher
National Academies Press
Washington, DC
E-mail: jkotcher@nas.edu

Stephen E. Lyons
Moreno-Lyons Productions LLC
Arlington, MA
E-mail: stephenlyons@comcast.net

Alisa Zapp Machalek
National Institutes of Health (NIH), National Institute of General Medical Sciences (NIGMS)
Bethesda, MD
E-mail: alisa.machalek@nih.gov

Anthony Marino
California Science and Technology Policy Fellow
E-mail: tomarino@gmail.com

Nancy McCormick-Pickett
Office of Public Affairs
American Chemical Society
Washington, DC
E-mail: N_McCormick-Pickett@acs.org

John J. McGrath
Division of Chemical, Bioengineering, Environmental, and Transport Systems
National Science Foundation
Arlington, VA
E-mail: jmcgrath@nsf.gov

Marjorie Mikasen
Lincoln, NE
E-mail: hardedge@inebraska.com

John Miller
Office of Basic Energy Sciences
U.S. Department of Energy
Washington, DC
E-mail: John.Miller@science.doe.gov

Joy Moore
Global Partnerships
Seed Media Group
New York, NY
E-mail: moore@seedmediagroup.com

Judith Nordgren
Marketing and Communications
The Vinyl Institute
Alexandria, VA
E-mail: jnordgren@vinylinfo.org

Mary Ostrowski
Chlorine Chemistry Division
American Chemistry Council
Arlington, VA
E-mail: Mary_Ostrowski@americanchemistry.com

Esther Peña
Communications Outreach
ACS Green Chemistry Institute®
Washington, DC
E-mail: E_Pena@acs.org

Martyn Poliakoff
School of Chemistry
University of Nottingham
Nottingham, England
E-mail: Martyn.Poliakoff@nottingham.ac.uk

Peggy L. Preusch
Towson University and the Smithsonian National Museum of Natural History
E-mail: ppreusch@umd.edu

Susanne Rehn
Deutsches Museum
München, Germany
E-mail: s.rehn@deutsches-museum.de

Michael E. Rogers
Pharmacology, Physiology, and
Biological Chemistry Division
Bethesda, MD
E-mail: rogersm@nigms.nih.gov

Eric Rohlfing
Office of Basic Energy Science
U.S. Department of Energy
Washington, DC
E-mail: Eric.Rohlfing@science.doe.gov

Joel Rosenberg
Digital Production
Lawrence Hall of Science
University of California, Berkeley
E-mail: jrosenberg@berkeley.edu

A. Maureen Rouhi
Chemical & Engineering News
Washington, DC
E-mail: M_Rouhi@acs.org

Glenn Ruskin
Office of Public AffairsAmerican Chemical Society
Washington, DC
E-mail: G_ruskin@acs.org

Jorge Salazar
EarthSky
Austin, TX
E-mail: jsalazar@earthsky.org

Erika C. Shugart
Marian Koshland Science Museum
National Academy of Sciences
Washington DC
E-mail: eshugart@nas.edu

Wade Sisk
Office of Basic Energy Sciences
U.S. Department of Energy
Washington, DC
E-mail: wade.sisk@science.doe.gov

James M. Solyst
ENVIRON International Corporation
Arlington, VA
E-mail: jsolyst@environcorp.com

Terri M. Taylor
K-12 Education
American Chemical Society
Washington, DC
E-mail: T_Taylor@acs.org

Patricia A. Thiel
Iowa State University
Ames, IA
E-mail: thiel@ameslab.gov

Levi T. Thompson
University of Michigan
Department of Chemical Engineering
Ann Arbor, MI
E-mail: ltt@umich.edu

Andrea Twiss-Brooks
John Crerar Library
University of Chicago
Chicago, IL
E-mail: atbrooks@uchicago.edu

David Ucko
Division of Research on Learning in Formal and Informal Settings
National Science Foundation
Arlington, VA
E-mail: ducko@nsf.gov

Sarah Weston
Saint Mary's University
Halifax, Nova Scotia, Canada

Robert Wiacek
Pixelligent Technologies, LLC
College Park, MD
E-mail: rwiacek@gmail.com

Ruth Woodall
Scholars
Nashville, TN
E-mail: ruth.woodall@tnchamber.org

Peter Yancone
Maryland Science Center
Baltimore, MD
E-mail: Pyancone@marylandsciencecenter.org

E

Origin of and Information on the Chemical Sciences Roundtable

In April 1994 the American Chemical Society (ACS) held an Interactive Presidential Colloquium entitled "Shaping the Future: The Chemical Research Environment in the Next Century."[1] The report from this colloquium identified several objectives, including the need to ensure communication on key issues among government, industry, and university representatives. The rapidly changing environment in the United States for science and technology has created a number of stresses on the chemical enterprise. The stresses are particularly important with regard to the chemical industry, which is a major segment of U.S. industry, in terms of trade and employment opportunities for a technical workforce. A neutral and credible forum for communication among all segments of the enterprise could enhance the future well-being of chemical science and technology.

After the report was issued, a formal request for such a roundtable activity was transmitted to Dr. Bruce M. Alberts, chairman of the National Research Council (NRC), by the Federal Interagency Chemistry Representatives, an informal organization of representatives from the various federal agencies that support chemical research. As part of the NRC, the Board on Chemical Sciences and Technology (BCST) can provide an intellectual focus on issues and fundamentals of science and technology across the broad fields of chemistry and chemical engineering. In the winter of 1996 Dr. Alberts asked BCST to establish the Chemical Sciences Roundtable to provide a mechanism for initiating and maintaining the dialogue envisioned in the ACS report.

The mission of the Chemical Sciences Roundtable is to provide a science-oriented, apolitical forum to enhance understanding of the critical issues in chemical science and technology affecting the government, industrial, and academic sectors. To support this mission the Chemical Sciences Roundtable will do the following:

- Identify topics of importance to the chemical science and technology community by holding periodic discussions and presentations, and gathering input from the broadest possible set of constituencies involved in chemical science and technology.
- Organize workshops and symposiums and publish reports on topics important to the continuing health and advancement of chemical science and technology.
- Disseminate information and knowledge gained in the workshops and reports to the chemical science and technology community through discussions with, presentations to, and engagement of other forums and organizations.
- Bring topics deserving further in-depth study to the attention of the NRC's Board on Chemical Sciences and Technology. The roundtable itself will not attempt to resolve the issues and problems that it identifies—it will make no recommendations or provide any specific guidance. Rather, the goal of the roundtable is to ensure a full and meaningful discussion of the identified topics so that the participants in the workshops and the community as a whole can determine the best courses of action.

[1] American Chemical Society. 1994. *Shaping the Future: The Chemical Research Environment in the Next Century.* Report from the Interactive Presidential Colloquium, April 7-9, Washington, D.C.