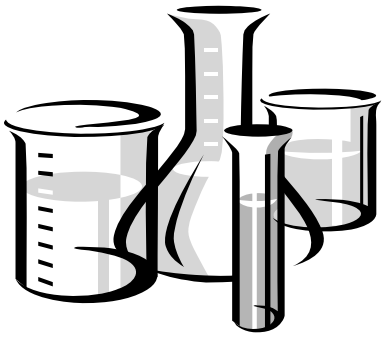
THE FUTURE OF CHEMISTRY AND MULTIDISCIPLINARITY

REPORT OF THE ACS BOARD-PRESIDENTIAL TASK FORCE ON MULTIDISCIPLINARITY



May 8, 2005

Report of the Board-Presidential Task Force on Multidisciplinarity

One-Page Synopsis

The task force's vision of the Society is a professional society that facilitates the development of new and emerging areas located along the interface of chemistry.

ACS Membership. Our recommendation is to be inclusive and to relax the ACS membership admission standards. Anyone who professes an interest in chemistry and pays the membership dues is welcome.

ACS Organization. We recommend four alternative organizational models for the ACS in the future. A key element is the use of topical groups to grow new areas, to recruit members, and start new journals, meetings, and educational initiatives. The topical groups can form, grow, change, or disappear, depending on need. The Chemical Abstracts data on publication frequency of different research topics can be used to monitor emerging fields, to identify active researchers, and to start new topical groups.

Meetings. The meetings should be more dynamic and more inclusive of diverse fields. We recommend horizontal programming across different fields, with national meeting programs (partly) organized by 8-12 themes. A second recommendation is to use electronic/web meetings as an alternative meeting mode. We should help the topical groups grow. One recommendation is to empower topical groups to develop small, focused, topical meetings.

Publications. The ACS Publications is doing well responding to new trends and starting new journals as needed. We recommend that as 8-12 themes are identified for national meetings, the ACS clearly defines which ACS journals welcome the manuscripts under each theme. Other desirable items to be explored include partnerships with journals from other countries, partnership with other search engines to augment SCI Finder, and the development of customized alerts to identify significant events in selected fields.

Education. The ACS Education Division is doing a great job on chemistry education. The multidisciplinary nature of chemistry is already incorporated into many of their programs, e.g., teacher training workshops, magazines, CD's, brochures, and other products. Curricular changes are needed to emphasize enabling chemical principles that connect the teaching materials to real-world, real-time applications and examples, with more emphasis on the increasing multi- and inter-disciplinary nature of chemistry. Textbooks are convenient media for change; the ACS can continue to sponsor or encourage textbooks that include the multidisciplinary perspectives. Continuing education courses on multidisciplinary and interdisciplinary areas are useful. We also need to recognize, incorporate, and encourage efforts of ACS members who work in multidisciplinary education areas.

We recommend that a multi-faceted approach be applied to communicate to the public the benefits that science [with chemistry as a major element] has brought to society.

Executive Summary.

The task force appreciates the opportunity to engage in this study. The task force's vision of the Society is a professional society that facilitates the development of new and emerging areas located along the interface of chemistry. We have examined the following issues: 1) ACS Membership, 2) ACS Organization, 3) Meetings, 4) Journals, and 5) Education. The following summary provides our thoughts and recommendations on these subjects.

ACS Membership. The major recommendation is to relax the ACS membership admission standards. We believe we should be as inclusive as possible. Anyone who professes an interest in chemistry and pays the membership dues is welcome. Since the multidisciplinary people are more likely to encounter the Technical Divisions, the divisions are in a good position to recruit new members. Membership growth should be global. Moreover, as our enterprise becomes more multidisciplinary, our award system also needs to change.

ACS Organization. We propose four possible organizational models for the ACS in the future:

- Conglomerate Model. The divisions are replaced with 50-80 topical groups, which seek to capture the active research areas. The groups can be started, grow, change, or disappear, depending on need. Coordination is needed at national meetings (e.g., through 8-12 themes).
- Division Plus Topical Group Model. The divisions function much like they do now except with administrative support from ACS staff. Additional topical groups are organized or disbanded as needed. Divisions and topical groups coexist. Divisions can start topical groups either on their own or in collaboration with other divisions.
- Subsidiary Model. A new ACS subsidiary is charged to grow new areas, start new journals, meetings, and topical groups. It can start new businesses or form JVs.
- Modifications of the *Status Quo*. Start a "multidisciplinary" Division to identify and help funding new areas. This division then commissions special interest groups to capture new or emerging areas of research.

One recommendation is to use Chemical Abstracts data on publication frequency of different research topics to see what fields are emerging, who the active researchers are, and (above all) what new topical groups to form.

Meetings. Whereas the current ACS meetings are successful, we believe perhaps some changes may be needed in view of the changing times. We need to make them more dynamic, more inclusive of multidisciplinarity, with more frequent turnover of topics, somewhat like the Gordon Conferences.

- Whereas the divisions do a good job within their fields, there is value in horizontal programming across divisions in view of multidisciplinary. One possibility is to designate 8-12 themes per national meeting where the divisions and the topical groups can submit papers. Part of the ACS Program Book can be organized by these themes, listing all the papers under each theme. Some routes to obtain these themes include P2C2 meetings, Division program chairs, topical group leaders, DAC, ComSci, and CAS data on publication frequency of research topics.

- A second recommendation is to use electronic/web meetings as an alternative means to reach a broad spectrum of people quickly.
- We should help the topical group grow. One recommendation is to empower some topical groups to hold small, focused topical meetings. Suitable *modus operandi* can be worked out for mutual benefit.
- In some multidisciplinary topics, it may be useful to partner with other scientific societies (e.g., joint meetings, symposia, or joint developments). These societies can be U.S. or non-U.S.
- A more drastic suggestion is to replace one of the two ACS national meetings with two or three sites with many meetings. Perhaps these smaller meetings can feature the topical groups and also actively solicit new topics. The purpose is to refresh the topics, bring meetings closer to members, and welcome conferees from other disciplines.

Publications.

- The ACS Publications is doing well responding to new trends and starting new journals as needed. It may be useful to check to see if we are capturing the state of the art with our current journals, especially in light of the trend towards multidisciplinarity.
- We recommend that as major themes are identified for national meetings, the ACS journal editors clearly define which ACS journal welcomes the manuscripts in a theme, or (if needed) recommend the start of a new thematic journal.
- We recommend that the Society investigate ways to partner to gain access to other search engines to augment SCI Finder.
- We recommend that ACS develop a series of customized alerts to identify significant events in a field.
- A suggestion was made to partner with the national chemical societies in rapidly growing countries. Some of these countries are producing increasing number of chemists, and it will be useful to gain access to these chemists.

Education.

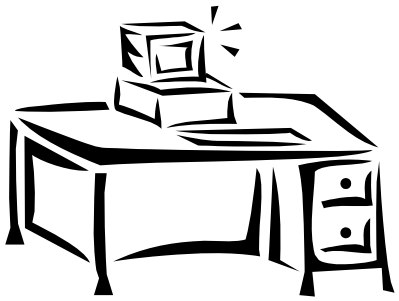
- In view of the changes in the chemistry enterprise, we see a spectrum of changing educational needs and opportunities in the future: high school, undergraduate, graduate, continuing education, and public literacy.
- Curricular changes are needed to emphasize enabling chemical principles that connect the teaching materials to real-world, real-time applications and examples, with more emphasis on the increasing multi- and inter-disciplinary nature of chemistry.
- An example with linkage between learning and applications is given below. The students work on problems even as they learn.
    - Freshman: Emphasize the key chemical principles and the integration of these principles with real world examples and applications.
    - Sophomore/Junior: Provide further course work, with in-class or in-lab integrated projects.
    - Senior: Several options are possible: a) depth in a specific topic, b) participation in multidisciplinary capstone course, c) group workshop or project, which enhances the students' soft skills, or d) senior research thesis. Many of these topics should be interdisciplinary to enhance the students' exposure to different disciplines.
- Explore mechanisms for restructuring both the organization of chemistry departments and

the curriculum organization/content, in order to strengthen the multidisciplinary approaches.

- Textbooks are convenient media for change. In view of multidisciplinarity, perhaps a review of the chemistry-related textbooks is desirable. The ACS can continue to sponsor or encourage textbooks that include the multidisciplinary perspectives.
- With the rapid changes in chemistry and in the workplace, continuing education for chemical professionals is ever more important. Workshops and continuing education courses on multidisciplinary and interdisciplinary areas are useful.
- We need to recognize, incorporate, and encourage efforts of ACS members who work in multidisciplinary education areas.
- We should partner with other disciplines to build connections and work on curricular changes. The other disciplines are probably just as interested in multidisciplinarity as we are. By working together, we can all benefit.
- The ACS Education Division is doing a great job on chemistry education. The multidisciplinary nature of chemistry is already incorporated into many of their programs, e.g., teacher training workshops, magazines, CD's, brochures, and other products.
- Already many resources on multidisciplinarity are available, e.g., new teaching materials, ACS recommended URL's, and ACS Division of Chemical Education, Inc. (CHED) and other programs at national meetings. These activities should be promoted and expanded.

We recommend that a multi-faceted approach be applied to communicate to the public the benefits that science [with chemistry as a major element] has brought to society.

In all the topics described, we often discussed the use of new technologies and tools. These may be advantageous, not only for convenience but perhaps also in the commercial context. Some examples are improved transmission of information at meetings, web-based lectures, symposia, and books, web-based topically focused "forums", iPod-based lectures, and virtual chemical experiments.



I. Introduction

Since the 1990's, there have been significant shifts in occupational title changes for chemical professionals as well as changes in what chemists do, where they work, and what kind of degrees they are obtaining**.** In particular, since chemistry and science in general are becoming increasingly multidisciplinary in scope and practice, it is no longer possible to draw a clear boundary around chemistry as it continues to disperse throughout other sciences. In view of these changes, the ACS Committee on Economic and Professional Affairs (CEPA) recommended in December 2003 that the ACS Board of Directors create a task force to monitor and assess the impact of the dispersion of chemistry.

Coincidentally, a recent National Research Council report "Beyond the Molecular Frontier" by Ronald Breslow and Matthew Tirrell proposed that research in the chemical sciences will become increasingly interdisciplinary in order to address successfully the complex technological problems we face. Chemistry will regularly intersect with the biological sciences, physics, engineering, computer science, and mathematics as partners in the R&D enterprise.

In view of these developments, the ACS Board of Directors and President Charles Casey created this task force in the summer of 2004. The task force is charged to assess the potential impact of multidisciplinarity and the challenges and opportunities it presents to chemical scientists and ACS.

A preliminary report has been issued on March 8, 2005, prior to the ACS national meeting in San Diego. Since then, further input has been received. In this final report, the task force presents its findings and recommendations to the ACS President and to the Board.

II. Task Force Membership

The task force currently consists of ten members:
Paul Reider, Chair (Amgen)
H. N. Cheng, Associate Chair (Hercules)
Nancy Jackson, Discussion Leader, Membership (Sandia)
Deborah Leckband, Discussion Leader, Education (Univ. of Illinois, Urbana-Champaign)
Cynthia Maryanoff, Discussion Leader, Meetings/Publications (Cordis Corp.)
Jean Chmielewski (Purdue Univ.)
Richard Crooks (Texas A&M Univ.)
Paula Hammond (MIT)
Sangtae Kim (NSF and Purdue Univ.)
James Yardley (Columbia Univ.)

The task force has been blessed with the active participation and input of Dwight Chasar, DAC Chair (Noveon), and Anne O'Brien, Board member. The task force benefited from a San Diego panel discussion organized by Anne O'Brien and Nancy Jackson, and from discussions and comments from many individuals, particularly Bill Carroll and Chuck Casey, ACS Presidents, Jim Burke, Board Chair, Marinda Wu, CEPA Chair, and members of CEPA.

Three members of the ACS Membership Division provided valuable support and advice: John Katz, Alicia Harris, and Michael Shea. The ACS staff liaison is Shea.

III. Task Force Activities.

In view of the geographical separation of the task force members, much of the early discussions took place via conference calls. Two face-to-face meetings in Dallas in January and April were most helpful to bring out different ideas and to reach consensus. A web site was created by the ACS staff in February 2005: http://membership.acs.org/m/multidiscipline/. The web site contains a number of relevant articles on multidisciplinarity (collected by task force members) and also solicits input from the ACS membership at large.

IV. Notes from Discussions

The task force's vision of the ACS is a professional Society that facilitates the development of new and emerging areas located along the interface of chemistry. We do not serve chemists only; we serve everyone who uses chemistry to advance science. We view the ACS as the place for scientific ideas and communities to nucleate and proliferate. Thus far, we have examined the following issues: 1) ACS Membership, 2) ACS Organization, 3) Meetings, 4) Journals, 5) Education, and 6) Other Issues. The following write-up provides our thoughts and recommendations on these issues.

A. Membership-Related Issues

1. Relax ACS membership admission standards because they are too stringent. The suggestion is to use only two primary requirements:
   - professed interest in chemistry
   - payment of membership dues

A variation of the theme is to have a two-tiered membership structure: a general membership (with the above two requirements) and a professional membership that requires additional evidence of professional qualification

2. Technical Divisions become more responsible for ACS member recruitment
   a. The Technical Divisions provide structure and long-term organizational units for technical activities. Ideally this is the place where technical people can go for a long-term association
   b. ACS to be more supportive of division-only membership
   c. Division membership to be used to recruit new multidisciplinary members and multidisciplinary topical groups
   d. Recruitment not limited to people with chemistry background. Be inclusive. Recognize that broad multidisciplinary teams (including social scientists) will be necessary to solve the problems of the future.

3. We encourage development of partnerships with other U.S. and non-U.S. professional societies to recruit a more diverse and global membership.

4. Award structure needs to change
   a. Complete overhaul of system
   b. More dynamic award system
   c. More multidisciplinary
   d. Less overlap in traditional fields
   e. More awards given to younger people
   f. If money is donated to fund an award (endowed), topic of award should be decided by the ACS.

B. Proposals Concerning ACS Organization

In view of changing times, we propose four possible organizational models for the ACS in the future:

1. *Conglomerate Model.* The divisions are replaced with 50-80 topical groups, which seek to capture the active research areas. The groups can be started, grow, change, or disappear, depending on need. These need no (or few) by-laws and can be optionally affiliated with Divisions. They can be populated by either members or non-members. Coordination is needed at national meetings (e.g., through 8-12 themes).
2. *Division Plus Topical Group Model*. The divisions function much like they do now except with administrative support from ACS staff. Additional topical groups are organized or disbanded as needed. Divisions and topical groups coexist. Divisions can start topical groups either on their own or in collaboration with other divisions.
3. *Subsidiary Model.* A new ACS subsidiary is charged to grow new areas, start new journals, meetings, and topical groups. It can start new businesses or form JVs.
4. *Modifications of the Status Quo.* Start a "multidisciplinary" Division to identify and help funding new areas. This division then commissions special interest groups to capture new or emerging areas of research.

Our recommendation is to use CAS data to start new topical groups.

- Pubs already use these data to start/replace journals
- We can use these data to see what fields are emerging, what new topical groups to form, and who are the active researchers.

We can conceptualize the relationship between the disciplines and topical groups as a matrix. The main disciplines (physical, organic, inorganic, analytical, polymer, biological, medicinal, electronic, information science, etc.) can be placed on the y-axis, and the topical groups on the x-axis. Each topical group can have components from one or more disciplines.

A variation of the Conglomerate and the Subsidiary Model is to create our own boutique societies that would either laterally 'orbit' around the ACS, or fall under the parent company as a subsidiary, called "International Society for Molecular Sciences" (as suggested by Bill Carroll). We can also absorb or collaborate with some existing boutique societies. An appropriate screen is needed to identify and prioritize these potential add-on societies.

We are aware that many of the above models may require changes in ACS by-laws and financial paradigms. These may be issues for the ACS governance to consider.

C. Meetings

Whereas the current ACS meetings are successful, we believe perhaps some changes may be needed in view of the changing times.

1. Questions on ACS Meetings
   a. Are we capturing the latest technology through our traditional meeting format?
   b. Can we learn from the Gordon Conferences, which often change their topics?
   c. How can we re-design meetings to make them more dynamic and inclusive of new people and the latest breaking results?
   d. Can we produce faster turnaround on programming for meetings?

2. What is New? Some examples from Chemistry Enterprises 2015:
   a. Nanoscience and Nanotechnology
   b. New Materials
   c. Enzymes
   d. Bioprocesses at Extreme Conditions

3. Horizontal Programming at ACS Meetings

We need to re-examine the process by which technical divisions program on strategically important topics whose audience extends across two or more divisions.

   a. Depending on the topic being addressed, some divisions will need to view the consumers of their information products as extending well beyond their individual division's vertically structured membership. Many divisions address topics that offer value to other division members, not to mention scientists from other professional societies. Understanding the horizontal (multidisciplinary) appeal <u>of some parts of their technical programs</u> will open the eyes of division program chairs to operate in a non-traditional manner.
   b. Divisions need to collaborate in advance on whom will be responsible for addressing which particular aspect of a topic that crosses division lines. [This will help avoid instances in which aspects are inadvertently duplicated, or worse, skipped].
   c. Divisions need to work together to schedule consecutively – rather than concurrently - sessions addressing topics whose audience extends across two or more divisions.

4. Identify 8-12 major themes as topical areas at national meetings
   a. Use the themes to guide programming at national meetings
   b. How to identify the themes? Some routes to obtain these themes include P2C2 meetings, Division program chairs, topical group leaders, DAC, ComSci, and CAS data on publication frequency of research topics.
   c. Get experts in those fields and engage divisions and topical groups
   d. We may need to distinguish between 'big themes' like nano, energy, biotech, etc. and lesser themes (themelets) that do not as yet have quite the mass of big themes.
   e. Some sort of benchmarking/evaluative process is needed to determine how topics get to the big theme status and what constitutes critical mass for a themelet. (The themelets are important, and some may become new foci for the future.)

5. We recommend that a mechanism for electronic or web meetings be supported by ACS. The electronic/web meetings are compatible with the work habits of the Milennium and Gen-X groups. These should be user-friendly and readily adaptable.

6. We should help the topical groups grow. One recommendation is to empower some topical groups to hold small, focused meetings. Suitable modes of operation can be worked out for mutual benefit. For example, the program and speakers can be handled by the topical group leaders. The ACS may help with marketing, advertising, and meeting set-up. If we provide freedom for our scientists to gather focused meetings together, either in person or virtually (electronically), our multidisciplinary topical groups can more easily flourish.

7. The issue arises as to the funding of small meetings. The details can be worked out later. It is felt that if we put on quality meetings, people will come and will be willing to pay reasonable fees. One example for a stand-alone meeting was the joint ACS/IEEE/MRS meeting on organic electronics expecting to attract 100-125 attendees, and fees were anticipated to be in the realm of $450 for a 2.5 day meeting.

8. For newly emerging and multidisciplinary topics, there appear to be benefits for both small-meeting and national-meeting formats. Both modes may be employed, depending on need. It is often easier, cheaper, and useful to hold small meetings to discuss a focused topic. On the other hand, there are advantages to having the topical meeting in collaboration with national (or regional) meetings, e.g., a) injection of new ideas from wider range of chemists; b) exposure of the topic to more chemists who can generate new ideas, c) Small groups get incestuous very fast; more attendees bring more perspectives and more information. One option is to hold these topical meetings at/with national meeting or else immediately afterward, saving travel time and costs for at least the chemical members.

9. There is a need to coordinate and transmit multidisciplinary activities
   a. Need to establish the communication tools necessary for division program chairs and topical group leaders to collaborate.
   b Use P2C2 meetings, perhaps quarterly, to communicate. Attendees identify emerging topics from their respective groups. More topics may surface at the P2C2 meetings.
   c. Encourage Long Range Planning for program chairs and topical group leaders.
   d. Make market data available to set up programming in topical areas at national and regional meetings.

10. Encourage multidisciplinary initiatives
   a. Change meeting allocation and reward structure to encourage programming in multidisciplinary areas.
   b. In addition to the usual meeting support (venue, literature, advertising, etc.), the ACS can also take the initiative in helping to identify and create new topical conferences/symposia.
   c. Provide staff support for various activities resulting from multidisciplinary initiatives.

11. ACS staff needs to market these programs and information products across relevant technical divisions, and to relevant external scientific societies.

12. As for regional meetings, we felt that these should be topically focused. Many regional meetings are already doing this and may represent good models.

13. Partnering/collaborating with other professional societies:
   a. We need to work with other professional societies when addressing those multidisciplinary subjects that require the presence of non-chemists for enhanced understanding
   b. The partnership may take the form of joint meetings, symposia, or joint developments

14. We should think "international" for all of the above. There is no reason not to collaborate with societies in other countries. We note that Asia (e.g., China, India, South Korea, and Singapore) is where a lot of action is today and will be more so in the future.

15. A more drastic suggestion is added here. The idea is to eliminate one of the ACS national meetings and replace it with two or three fixed sites for smaller meetings. One would send in a proposal to the ACS for a meeting (say 10-200 participants), and if approved the meeting would be scheduled at one of the fixed year-round sites. It is felt that this is a sure-fire way to keep the topics fresh, welcome conferees from other disciplines, and bring the membership more into the planning process.

D. Publications

The ACS Publications is doing well responding to new trends and starting new journals as needed. Here we provide some suggestions with respect to multidisciplinarity.

1. Question on ACS Publications
   a. Do we capture the state-of-the-art with our current journals, especially in view of multidisciplinarity? For example, organic chemistry has JACS, JOC, and Organic Letters. Are they adequate?
   b. Are the ACS journals competitive in publication speed? Note the increased load of submissions and limited editorial staff and assistance in some cases.
   c. Are the journals strategically situated? For example, we do not have a place for electrochemistry (until recently), but we have duplication in other areas.
   d. How to handle topics addressed across several journals? Is it wise to require scientists in a multidisciplinary field to consult with 3-4 different ACS journals? What to do about editors who put the interests of their journals above the collective interest of the researchers in a given field? And above the business interests of the ACS?
   e. How to handle topics that are important but may not be important enough to warrant a separate journal. This is the theme vs. themelet issue in the print context.

2. We discussed earlier the organization of national meetings by 8-12 themes. It will be useful for the ACS journal editors to clearly define which ACS journal welcomes the manuscripts in a theme, or (if needed) consider the need for a new thematic journal.

3 There are threats looming with respect to Pubs (e.g., Open Access and Google), and CAS

(NIH's PubChem). For example, Open Access has enormous implications for how ACS and other scientific publishers conduct business in a multidisciplinary environment. The preliminary policy adopted by the ACS for access after one year is a good start.

We recommend that the Society investigate ways to partner to gain access to other search engines to augment the SCI Finder. Other search engines currently provide valuable search information that the SciFinder does not access, e.g., non-peer reviewed articles or papers written by university students, reports/fact sheets posted by suppliers of technology, etc. Typically this information, while not reviewed or otherwise 'authenticated', provides an alternative source of information to understand where a field is going.

4. Customized Alerts
   a. A business opportunity is for the ACS to develop a program of customized alerts to identify significant events in a field. Time is one of our most valuable assets. Offering professionals a portfolio review customized by requestor would add much value.
   b. The idea is to have experts evaluate the literature, make a value judgment of significance, condense the information and make it available as customized alerts [for a fee]. Filtering information published in ACS journals or abstracted from non-ACS journals by CAS and highlighting them in a customized manner with a focus toward multidisciplinarity is a timesaving feature to which members would subscribe.
   c. The question is whether people will be willing to pay enough money for this service.

5. Partnering

   a. We recommend partnering with other societies, U.S. and non-U.S., in order to maintain a global leadership position. Some multidisciplinary topics, in order to be understood most thoroughly or quickly, require the active involvement of scientists other than chemists, such as biologists, physicists, engineers, etc. The same rationale for co-organizing meetings with other scientific societies would seem to apply in the co-publication arena. Concerns over long-term co-publication agreements, and what would happen if the relationship turned sour might be mitigated by merely agreeing to jointly publish special issues. Concerns over the ACS entering into inter-societal arrangements, that result in ACS doing most of the work though equally sharing revenues, can be avoided by negotiating agreements that prevent such outcomes.
   b. Investigate opportunities that may exist with respect to partnering with for-profit publishers such as Wiley or Elsevier – particularly on subjects not addressed by an ACS journal.
   c. We recommend partnering with the national chemical societies in rapidly growing countries. Some of these countries are producing increasing number of chemists, and it will be useful to gain access to these chemists.

6. The challenge and the opportunities offered by electronic advances and future publications are illustrated by a symposium organized by the National Academies: (http://books.nap.edu/catalog/10969.html).
A presentation given by R. Bovenschulte can be found at the following web site: http://www7.nationalacademies.org/bcst/PUB_Bovenschulte.pdf

E. Education

1. Desired Outcome
   - To educate the public in order to enable individuals to make informed decisions about science and technology.
   - To increase interest and enrollment in the chemical curriculum by emphasizing the social relevance and positive impact of chemistry in our daily lives, as well as the centrality of chemistry to many different disciplines.
   - To provide chemistry students with the intellectual and technical tools that will enable them to rapidly respond to advances in scientific knowledge, technological opportunities, and technological developments.
   - To integrate multidisciplinary topics into all levels of chemical education from kindergarten to continuing education.

2. Challenges and Opportunities in Chemical Education
   - Foundational Science. Chemistry is a foundational, enabling science. Chemistry, as a discipline, uniquely encompasses fundamental and applied aspects of chemical bonding, chemical structure, reactivity and transformation, catalysis, physical properties of materials, and chemical analyses.
   - Relevance. Students and administrations increasingly ignore or bypass chemistry for more relevant/topical disciplines such as biology. The challenge is to foster early and sustained intellectual engagement in chemistry by showing direct connections between the foundational chemical principles and real-world, current multidisciplinary applications.
   - Bridging disciplines. Science is increasingly multidisciplinary, and chemistry continues to play a central role in multidisciplinary areas of research and technology. Our challenge is to emphasize both the pivotal role of chemistry in these multidisciplinary fields and the applications of chemistry in emerging, multidisciplinary research and technology.

3. Needed Changes in Chemical Education (K-PhD)
   - The entire curriculum must train chemists to be versatile enough to meet new demands presented by rapidly changing scientific and technological opportunities and developments, especially with respect to multidisciplinarity.
   - Emphasize the social relevance of chemistry. There is a pressing need to reinforce the relevance of the underlying principles of the chemical curriculum in every day life at all educational levels. These central chemical concepts need to be linked to a wide range of familiar applications. Students need to see real world connections early and often, and to learn how their knowledge base can be used to solve problems in a broad range of areas.
   - Integrate concepts from industry (real world) and other disciplines into the classroom and laboratory. Use contextual learning to emphasize broad connections and applications. For example, organic chemistry labs could be developed in partnership with scientists at pharmaceutical companies to synthesize compounds of medicinal interest. Additionally, at some institutions, multidisciplinary lab courses have been developed in conjunction with other departments such as

materials science or bioengineering to develop cross-disciplinary lab projects and course materials.

- Explore mechanisms for restructuring both the organization of chemistry departments and the curriculum organization/content, in order to strengthen multidisciplinary approaches. Many obstacles to multidisciplinary activities within the ACS are mirrored in the divisional structures of chemistry departments, and the compartmentalization of different branches (divisions) of chemistry. Despite recent changes, most departments maintain the traditional department structure.

4. Educational Resources and Support
    - The ACS Education Division is doing a superb job of responding to emerging opportunities in chemical education. They are already addressing the multidisciplinarity of chemistry in their programs, e.g., teacher training workshops, magazines, CD's, brochures, and other products.
    - ACS should be the primary source of resources that enable chemistry instructors to efficiently and effectively modernize the curriculum. The ACS Education division already provides several resources that are beginning to address multidisciplinary topics in the context of chemical education. This includes ACS sponsored or endorsed teaching materials, programming at national meetings, and continuing education **(Appendix 1)**. These activities should be promoted and expanded.
    - Textbooks are convenient media for change. The ACS can continue to sponsor specific K-12 and undergraduate textbooks that include multidisciplinary perspectives.
    - ACS should review web-based materials and serve as a clearinghouse for ACS recommended URLs focused on multidisciplinary chemical education. There are already websites that provide examples that integrate multidisciplinary topics into the chemistry curriculum. The ACS has a unique opportunity to provide the quality control and to serve as a clearinghouse for these resources.
    - The ACS should develop partnerships with other professional societies, in order to develop educational materials that provide a rigorous chemical foundation while meeting the educational objectives and needs of these other disciplines.

5. Continuing Education
    - With the rapid changes in chemistry and in the workplace, continuing education for chemical professionals is increasingly important. The ACS should encourage workshops and continuing education courses on useful/topical multidisciplinary and interdisciplinary areas.
    - ACS should inform its members of emerging areas in science and technology.
    - ACS can provide short courses and workshops on chemistry-related topics, incorporating multidisciplinary topics.
    - ACS can organize teacher-training workshops that focus on emerging areas and new instructional aids.
    - ACS could expand its offerings of web-based courses, and should work with state certification boards to recognize these activities for teacher training and certification.

6. Other Needs
    - Standardized tests such as the SAT, GRE, etc. often influence course content. These may be topics for further investigation.
    - There are perceived current needs in soft skills (e.g., communication and teamwork), exposure to different cultures, and continuing education for teachers. Mechanisms may be sought to address these needs.
    - Some web-based educational materials at the middle school and high school level are available. More materials are needed that are designed to help both students and teachers.
    - How to facilitate continuing education for teachers relating to multidisciplinarity? How do we help teachers obtain the credits their profession requires? Note travel difficulties and time constraints of teachers when offering them assistance.
    - Many ACS members are making efforts in multidisciplinary education, through their research, new courses, and new pedagogical approaches. The ACS needs to recognize, incorporate, and encourage the successful efforts of these members who excel in multidisciplinary education.

7. Educating the Public
    - ACS has some ongoing programs to educate the public. Multidisciplinarity may provide opportunities for better publicity.
    - We recommend that a multi-faceted approach be applied to communicate to the public what science [with chemistry as a major element] enables society to enjoy. The goal here is to strengthen the current efforts by the ACS on outreach. What does multidisciplinary science enable for the good of society? Our chemical enterprise is changing rapidly and we need to capture the good provided to all.
    - Ideally it would be useful to have some headlines in the news, reporting positive things from the chemical/multidisciplinary communities.
    - We recommend consideration of a POD broadcast of some sort every night. Blog communication effectively channeled may capture Milennium and Gen-X groups.
    - How about a chemistry magazine similar to *The National Geographic*?
    - A further suggestion is to produce and distribute a set of posters, similar to what the APS has done. Another example from the Columbia nanocenter is a public video presentation for NOVA that casts chemists in a positive image. Perhaps this is something that ACS should support/sponsor.

F. Other Issues

1. ACS employment services may need to change due to the multidisciplinary trend.
    a. More diverse employers
    b. More career counselors with multidisciplinary background
    c. Surveys need to reach out and find multidisciplinary people

2. Continuing education may need to be expanded.
    a. Multidisciplinary topical areas to be included.
    b. Web-based courses are relatively economical and may be preferred.

3. More planning and mechanisms may be needed.
   a. Recommend that ACS identify all the interfaces between chemistry and other disciplines, and prioritize them according to strategic importance. The thinking is that we have limited resources to pursue all the interface opportunities and that we first pursue those that matter most to the future health of the ACS
   b. A plan is needed to tackle hot areas in multidisciplinarity and take advantage of them.
   c. Coordinate with CAS on the information relating to emerging areas

4. Changes in meeting logistics and operations may be needed
   a. Decrease timeframes for the OASys. Push the deadlines closer to the meeting dates
   b. Design tools for the right topics
   c. Locate symposia on related topics in nearby hotels at national meetings
   d. Provide the appropriate staff support for ACS Technical Divisions and topical groups

5. As chemistry becomes multidisciplinary, more needs may arise among some ACS members, e.g., chemical technicians, contractors and temporary workers, "mature" scientists, and members working in international locations.

6. Use of new enabling tools

In all the topics described, we often discussed the use of new technologies and tools. These may be advantageous, not only for convenience but perhaps also in the commercial context. For example, the new technologies may allow faster and better presentation of information at meetings and provide opportunities for new products and services. Technologies also exist to track attendance at sessions to get feedback on successful and unsuccessful sessions. Some examples have been mentioned before. Other examples are shown below:

- Web-based lectures, symposia, and books
- Web-based topically focused "forums"
- How-to questions
- Reviews of products/services from vendors
- Links to, and discussions regarding articles published in journals and elsewhere
- iPod-based lectures
- Virtual chemical experiments.
- Global interfaces in general

Appendix 1. ACS Educational Resources

A. Resources available on the ACS Website (chemistry.org/education)

1. Textbooks

The ACS Education Division has developed a number of texts presenting key chemistry concepts in a multidisciplinary context, including
Chemistry in the Community (high school)
Science in a Technical World (high school, modular)
Chemistry in Context (non-major undergraduate)
Chemistry (first-year undergraduate)

2. Magazines

ChemMatters (high school)
in Chemistry (undergraduate)

3. Green Chemistry

Collection of supplementary educational materials to integrate green chemistry into the curriculum, including
Introduction to Green Chemistry (high school)
Going Green: Integrating Green Chemistry into the Curriculum (undergraduate)
Real-World Cases in Green Chemistry (undergraduate)
Greener Approaches to Undergraduate Chemistry Experiments (undergraduate)

B. CHED Programming

1. Relevant symposia at the 2005 National meeting

"Exploring the Molecular Vision: Multidisciplinary Approaches to Curricular Reform"
"Learning chemistry through policy issues and civic engagement"
"Educating biochemists for the future not the past"
"Whither goest physical chemistry? What's new for incorporating into the curriculum?"
"Chemistry for the health sciences"

2. Ongoing CHED activities

Biennial Conference on Chemical Education
CONFCHEM: Conferences on Chemistry

C. Continuing Education

1. Short courses

Example of multidisciplinary short courses:
Antibiotics and anti-bacterial agents
Chemical and biological mechanisms in toxicology
(Currently bio-focused courses are the only explicitly multidisciplinary topics covered. There are no internet or video courses that address multidisciplinarity.)

2. Others

CEPA Open Forum at San Diego National Meeting (2005)
"Globalization, Employment, and Dispersion of Chemistry as a Discipline"