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Science Education Policies for Sustainable Reform

INTRODUCTION

The American Chemical Society (ACS) is the world's largest association of individual chemical scientists and engineers. To fulfill its mission as a congressionally chartered scientific and educational society, ACS has developed nationally acclaimed programs that support ongoing reform efforts in science education at all levels. ACS education programs begin at the pre-school level, continue through elementary, middle, and high school, and include undergraduate and graduate instruction in chemistry. ACS also offers continuing professional development workshops, short courses, and Internet courses for elementary and high schoolteachers and for mid-career chemists working in industry and academia.

The Society continues to play an important role in the development of national policies related to science education by providing advice to Congress and various federal agencies. The Society also provides comments on the annual budgets of the National Science Foundation (NSF) Education and Human Resources Directorate, and the U.S. Department of Education. This ACS involvement stems from the recognition that the increasing role of science and technology in the U.S. economy necessitates a modern and effective science education system.

This document, summarizing the science education policies of the Society, is directed toward practitioners and policymakers throughout the U.S. educational system. These policies are organized by educational level and topic of concern. Since the first version of this ACS policy document was published in 1989, many changes have occurred in science education. Nationally and at the state level, the standards-based movement is attempting to bring coherence to science curricula at the K–12 level, with mixed results. There has been an acceptance that standards-based science instruction should include an emphasis on hands-on, inquiry-based instruction to help K–12 students develop a knowledge and understanding of scientific ideas. They also need to understand how scientists explore and make sense of the natural world. Specifically, they need to understand how scientists use inquiry methods that involve making observations; posing questions; examining the literature to see what is already known through experimental evidence; proposing answers and explanations; testing hypotheses through experimentation; and communicating the results orally, in writing, and by other appropriate methods. However, while all states have developed content standards, few have developed science education assessments that are congruent with their state content standards.

The No Child Left Behind (NCLB) Act appears to be having an unintended negative impact upon the practice of hands-on science at the elementary and middle school levels in particular. Since science is not yet a federally mandated assessment, schools are emphasizing, and therefore funding, activities that they expect will directly affect student performance in reading and math, both of which are currently being assessed in compliance with NCLB. The impact that national testing of science knowledge will have in future years must certainly be closely monitored.

Efforts continue at the undergraduate and graduate levels to ensure that courses reflect the vitality and challenges of modern chemistry and that instruction methods model the most effective pedagogical techniques. The funding of the Undergraduate Chemistry Systemic Reform initiatives and the subsequent Adapt and Adopt program by NSF continue to influence reform efforts. In particular, the Peer-led Team Learning approach pioneered by the City University of New York continues to gain support.

Of special concern at the undergraduate level, as at all levels of education, is the need to develop new assessment instruments consistent with new instructional pedagogy to evaluate student learning outcomes, faculty effectiveness, and the curriculum. At the graduate level, there is a need to broaden the graduate experience to include more specific training in, for example, green chemistry and sustainability ethics, toxicology and safety issues, statistics, economics, communication skills, and working on team and multidisciplinary projects. There is also a need to provide mechanisms through which the graduate student interacts with a functioning advisory committee throughout the student's graduate career.

The year 2003 saw the release of the National Academy of Sciences study, *Beyond the Molecular Frontier*, delineating the exciting directions in which the chemical sciences and engineering will develop over the next 10 years. The ACS began a major effort to reexamine the chemistry education process at the undergraduate and graduate levels, through an invitational conference, "Exploring the Molecular Vision." This conference confirmed the view that a consideration of content reform cannot be separated from pedagogy.

ACS recognizes that the major strength of the U.S. education establishment resides in the educators, K–12 teachers and college faculty, who bring the excitement of science and learning to students. It is critical that our nation recruit and retain the most talented people from our diverse population for these roles and that they be supported and recognized for their efforts.

ACS has been involved in the educational reform movement for many years. Yet, for educational reforms to succeed, we must all recognize the long-term nature of the reform process. Reform must be sustained; it must not be viewed as a one-time or cyclical activity. Recognizing the importance of a sustained effort, ACS will continue to support nationwide efforts to

- Implement standards-based science education at the K–12 level;
- Promote the systemic reform of undergraduate and graduate chemistry programs;
- Provide lifelong professional development opportunities for science teachers and those who practice the chemical sciences;
- Encourage schools to use assessment instruments that measure a student's understanding of science and use of the methods of science, not just the student's ability to recall science facts;
- Develop national assessments of science achievement at the K-12 level that are in-line with the National Science Education Standards in terms of scope, content, and assessment of the broad range of understanding and abilities expected from effective science learning;
- Ensure that the resources are available within schools, colleges, and universities to encourage and support excellence in laboratory-based courses;
- Recruit and retain the best possible people, including members of underrepresented groups, for example, women, African Americans, Native Americans, Hispanics, and persons with disabilities), into the scientific disciplines; and,
- Promote a scientific curriculum that emphasizes scientific reasoning and scientifically validated data at all levels.
- Develop introductory chemistry courses for both general students and science students that emphasize the current and future solutions of real-world problems.
- Integrate chemistry core courses for undergraduates and graduates on an intra-disciplinary unifying concept basis that reflects how chemistry is actually practiced.
- Demonstrate the "enabling" concepts of chemistry useful for 21st-century, team-centered, multidisciplinary research through interactive courses and research at the undergraduate and graduate levels.

PRE-HIGH SCHOOL (K–8)

Students make many decisions regarding future coursework and career options during their pre-high school years. Even their pre-school experiences can have an influence on future choices. Thus, the curiosity and wonder shown by the youngest of learners about the natural world must be carefully nurtured. Teachers (supported and reinforced by school systems, communities, and policymakers) play a pivotal role in this nurturing process.

Teachers need to be confident in teaching science through interactive and inquiry-based modern courses, as defined in the *National Science Education Standards.*

I. Teacher Development

Recruitment and retention of teachers who are well prepared in science is of the highest priority for the future of our technology-based society. These teachers must represent our diverse population. Elementary and middle school teachers need a firm grounding in physical, biological, and earth/space sciences, as well as an understanding of science education research. Their exposure to pedagogical techniques should promote a familiarity with hands-on, inquiry-based instruction, and provide them with significant pedagogical content knowledge. They also need preparation and practice in integrating science with other subjects, especially mathematics. If they do not have this background, teachers may be unable to implement hands-on, inquiry-based science instruction.

To ensure that teachers with a science background teach science, some school systems use science specialists, even at the earliest grade levels, to deliver regular instruction in science subjects. As a result, science and mathematics may be taught as completely separate, rather than mutually supporting, subjects. To ensure that K–8 students receive quality science instruction, ACS supports

- Requiring all elementary school teachers to complete at least three college-level semesters of laboratory-based, inquiry-oriented science, including physical science, to meet minimum certification standards. Courses in mathematics and mathematics education should be parallel and complementary to the science courses. These courses should be developed as cooperative and creative efforts among departments of science, mathematics, and education.
- Requiring all middle school science teachers to complete at least 3 one-year, laboratory-based, inquiry-oriented college-level science courses, including physical science, to meet minimum certification standards. Courses in mathematics and mathematics education should be parallel and complementary to the science courses. These courses should be developed as cooperative and creative efforts among departments of science, mathematics, and education.
- Enhancing federal, state, and local funding of teacher in-service professional development programs to ensure that elementary and middle school teachers have access to programs that help them to expand and update their science knowledge base. These programs could take many forms, including technology-based remote learning. However, they must be designed to enhance teacher content knowledge in the sciences through the perspectives and methods of inquiry. This support should be directed at the courses most appropriate for building the skills needed. Most often, these will be undergraduate rather than graduate-level courses.
- Providing regular compulsory, teacher-led, in-service professional development programs in science and mathematics through the school system that include content, laboratory experience, and pedagogy. One effective way to accomplish this is to prepare and support groups of leadership teachers and scientists to operate statewide as teams of in-service facilitators.
- Requiring elementary and middle school teachers of science to take education courses that emphasize pedagogical content knowledge, peer-reviewed science education research, new knowledge on human cognition, and ways of reaching students with different learning styles, including the use of technology.
- Using science specialists and resource teachers where elementary teachers lack science knowledge, to motivate and assist non-specialist teachers in the presentation of science and its integration with other subjects, especially mathematics and reading.
- Making use of mentors and master teachers to aid and encourage new teachers.
- Using only certified science teachers to teach science at the middle school level.

- Increasing the involvement of high school teachers and students, and scientists from academe, business, and industry, as mentors for both teachers and students at the K–8 level. Partnerships with ACS local sections can be particularly useful in this regard.

II. Assessment

Individual states are developing instruments to assess student achievement and teacher competence in the sciences. Consultation with those professional organizations that have either already developed such instruments, or have the expertise to do so, must be encouraged. However, it must be recognized that assessment instruments do not always address the broad range of understanding and abilities expected from effective science learning. To address these concerns, ACS advocates

- Evaluating students' science achievement at all grade levels, during each grading period. Classroom evaluation should assess not only fact recall and concept comprehension, but also higher-level cognitive skills, including the ability to apply science knowledge in new situations. Evaluation tools should assess process skills using hands-on activities and computers, as well as paper-and-pencil exercises.
- Using the self-assessment guidelines for elementary school science teachers developed by the National Science Teachers Association and other professional organizations as a means of encouraging teacher self-reflection.
- Evaluating elementary teacher competence in science, in multiple ways and with carefully designed instruments, as a means of helping teachers identify areas in their science background that need additional professional development.
- Developing national assessment instruments designed to identify factors in the school community that lead to successful student learning of science, and working to strengthen those factors in every community.

III. Curricula

Informed by the content sections in the *National Science Education Standards* and the American Association for the Advancement of Science's Project 2061, *Benchmarks for Science Literacy,* all states now have state standards or frameworks for science curricula.

However, the quality of these standards varies from state to state. Even within a state, there may still be inconsistencies in the development of content from one grade to the next, or from one school district to the next. Science in elementary and middle schools should be a hands-on, inquiry-based exploration of the natural world, using multiple resources: teachers, the laboratory, the library, the wider community, books and magazines, multimedia sources, and the Internet. Chemical phenomena should be introduced in the early grades as a part of students' observations of their surroundings. To address these issues, ACS supports

- Developing inquiry-based K–8 curricula that reflect the conceptual frameworks provided by the content sections in the *National Science Education Standards*, the Project 2061 *Benchmarks*, and their state and local counterparts. Elementary, middle, and high school teachers should work together to make certain that science content is articulated and implemented throughout the K–12 system.
- Including some chemistry component at each grade level (K–8) developed by teachers and scientists working in partnerships.
- Developing safe, hands-on, inquiry-based science activities in which science as a problem-solving endeavor is placed within the societal context of the student, using concrete examples of science and technology and various technological resources.
- Using the computer for simulations, drills, access to multimedia and Internet resources, and enhancing data collection, but not eliminating laboratory experiences.

- Expanding efforts to integrate science with other curricular areas such as reading, mathematics, and social studies.
- Developing appropriate science experiences for very young children working with their parents.

IV. Resources

All schools at the K–8 level should consider science as an essential component of basic education. When the school administration, the school system, business and industry, and the local community (including parents) work in collaboration, effective elementary and middle school science instruction becomes more relevant. Adequate facilities and resources necessary to teach science at this level are essential. To ensure that adequate resources are available for teaching K–8 science, ACS urges

- Restructuring the elementary and middle school curriculum to allow time for daily, inquiry-based science activities and for teacher preparation of these activities.
- Furnishing elementary classrooms to permit safe, hands-on, inquiry-based science instruction (at a bare minimum, a sink and running water) and, at the middle school level, providing laboratory workstations. Access to adequate educational technology, including calculators, computers, and connection to the Internet, is a high priority. Of necessity, hands-on, inquiry-based science must be supported by adequate budgets for supplies, online access, and equipment and equipment maintenance.
- Involving parents in their children's science education by establishing both school- and community-based out-of-classroom science experiences for the family.
- Establishing school system/business/government/ACS local section alliances to introduce current science and technology information into the classroom on a regular basis. Such partnerships could include sabbatical leave programs, industrial and government laboratory summer employment, and other arrangements that permit exchanges of personnel between schools and the science-rich sectors.

SECONDARY SCHOOLS (9–12)

For many students, high school represents the single most significant period in their science education and a time when tentative career choices are made. Developing both a scientifically literate public and the science specialists needed to advance our nation in an increasingly complex technological world, demands intellectually challenging yet developmentally appropriate curricula taught by well-qualified teachers.

The ACS strongly supports a variety of approaches to the structure and the continuous evaluation and improvement of high school science curricula. We call attention to the ongoing changes that are taking place in the sciences and we believe that all students, college-bound and otherwise, should be well educated in the sciences and in the mathematics that are the driving engines of 21st century society throughout the world. We are cognizant of the national standards in science and mathematics that are providing models for state standards. Therefore, we strongly support developing new science curricula that are based upon a core three-year science program that

- Presents science in a logical and coherent sequence that reflects the connections among the disciplines,
- Stresses the relationships between mathematics and science,
- Strives for a balance between content and process, and
- Emphasizes inquiry and laboratory experience.

Teachers need to be comfortable teaching science through interactive and inquiry-based modern courses, and they need to be appropriately recognized and rewarded for their successes.

I. Teacher Supply

Many of our nation's teachers are reaching retirement age, and some are leaving teaching for other careers. Attracting well-prepared graduates into teaching careers will be a challenge. To encourage the brightest of our students among our diverse population to consider careers in teaching, ACS supports

- Establishing state and federally supported scholarships to assist undergraduates interested in teaching secondary school science or mathematics. These scholarships should be renewable for up to four years and include support of education-related, paid professional activities during the summers. After graduation, the students should be required to teach one year for every year of scholarship support.
- Establishing state and federally funded scholarships to support individuals holding a discipline-centered academic degree who need pedagogical courses for secondary school teacher certification. Scholarship recipients should be required to spend at least one year teaching science or mathematics in a secondary school.
- Modifying existing teacher certification programs to permit experienced scientists to teach in secondary schools after completing a suitable teaching internship, with the understanding that education course credits would be required for permanent certification.

II. Teacher Development

The ability to deliver quality instruction, and the professional status of secondary school science teachers, may be undermined by heavy teaching loads and limited opportunities for teachers' professional growth, especially in acquiring a stronger scientific background. The release of the *National Science Education Standards* and the Project 2061 *Benchmarks* challenges current teachers, and those preparing to teach, to achieve new levels of excellence in their teaching. To help meet these challenges, ACS advocates

- Requiring teachers to meet content area qualifications for the courses they are required to teach by taking appropriate undergraduate courses. Enhanced cooperation between departments of different disciplines and schools of education will be essential to ensure that teachers are well prepared in science content, pedagogy, and standards-based assessment techniques.
- Encouraging college and university education and science departments to develop programs that include content and pedagogy, to allow potential teachers to complete their certification requirements within a typical bachelors degree program.
- Enhancing federal, state, and local funding of professional development to ensure that secondary school science teachers have access to programs that allow them to expand and update their science knowledge base. These programs could take many forms, including technology-based remote learning. They must be designed to enhance teacher content knowledge in the sciences through the perspectives and methods of inquiry and hands-on experience.
- Requiring high school science teachers to take education courses that emphasize pedagogical content knowledge, peer-reviewed science education research, new knowledge on human cognition, and ways of reaching students with different learning styles, including the use of technology.
- Changing state requirements for continuing education of teachers to include more content-area subject matter. At present, teachers may be required to take graduate-level courses in pedagogy to maintain their certification, when undergraduate courses in the sciences might be more effective in enhancing classroom performance. College and university science departments should develop and offer appropriate classroom and/or distance learning courses for practicing teachers throughout the calendar year.
- Improving the work conditions of science teachers to reduce attrition from the profession, to help improve the quality of instruction, and to ensure that safety concerns are met. Conditions for chemistry teaching should be consistent with the recommendations in the ACS documents *Safety in Academic Chemistry Laboratories* and *Model Chemical Hygiene Plan for High Schools* and with the *National Science Education Standards.*

- Providing financial incentives to encourage the participation of teachers in summer research and other educational activities at college, university, industrial, and government laboratories.
- Providing mechanisms for more experienced teachers to mentor new teachers.

III. Curricula

Science curricula need to be challenging to the students, and based on the "real world" of student interactions with nature. The *National Science Education Standards* and the Project 2061 *Benchmarks*, together with state and local frameworks, present a consensus on which to build such curricula. The 2002 NRC report on improving advanced study of mathematics and science in U.S. high schools provides appropriate guidance on higher-level chemistry courses for second-year instruction. Inquiry-based learning and laboratory experiences are essential components of chemistry instruction at all levels (see addendum). To help meet consensus standards of excellence, ACS supports

- Developing science courses based upon inquiry-based learning, as defined in the *National Science Education Standards* and evaluating performance using standards-based assessment techniques. Classroom evaluation should assess not only fact recall and concept comprehension, but also higher-level cognitive skills, including the ability to apply science knowledge in new situations.
- Redesigning chemistry courses to present a broad view of the scope of modern chemistry by including such topics as organic, polymer, biochemistry, and materials science. The courses should include numerous examples of the interactions of science, technology, and society at all grade levels. They should also reinforce the role of the computer and laboratory instrumentation as scientific tools.
- Integrating within the laboratory experience an emphasis on environmental protection (including green chemistry) and laboratory safety.
- Integrating coverage of scientific ethics into the curriculum.
- Mandating at least three years of laboratory-based science for all secondary school students.
- Enrolling in Advanced Placement, the International Baccalaureate, or similar advanced programs as a second-year chemistry option.
- Exploring other logical sequences of science courses, for example, physics, then chemistry, then biology), organized in a manner that recognizes the dependence of each course in the proposed sequence on the content and concepts presented in the previous one.
- Integrating science content across disciplines and throughout the years of the secondary school experience.
- Enhancing articulation between high schools and two-year colleges, especially for students entering vocational training programs for technician-level jobs in science and engineering.
- Increasing the availability of out-of-school science activities for young people to reinforce interest in science and mathematics achievement and careers. Especially needed are out-of-school programs to attract underrepresented groups into the quantitative disciplines.
- Providing incentives such as scholarships to encourage the participation of all students in summer research activities at college, university, industrial, and government laboratories.

IV. Resources

All high schools should consider science as an essential component of basic education. When the school administration, the school system, business and industry, and the local community (including parents) work in collaboration, high school science instruction becomes more effective. Adequate facilities and resources are essential to teach high school science effectively. Business and industry in particular have a stake in ensuring that the educational system produces both scientifically literate citizens and technically trained/trainable personnel. To ensure that adequate resources are available for high school science, ACS urges

- Providing laboratory workstations that permit safe, hands-on, inquiry-based science instruction. Access to adequate educational technology, including calculators, computers, and connection to the Internet, is a high priority. Of necessity, hands-on, inquiry-based science must be supported by adequate budgets for supplies, equipment, online access, and maintenance.
- Establishing school/business/government/ACS local section alliances to introduce current science and technology information into the classroom on a regular basis. Such partnerships could include teacher sabbatical leave programs, industrial and government laboratory summer employment opportunities, and other arrangements that permit exchanges of personnel between schools and the educational and business sectors.
- Using tax incentives to encourage business and industry to become more involved in high school science education.
- Providing broad experiential programs for students during the academic year and summer, for example, ecological field experiences, participation in science fairs and science Olympiad events, science mentorship programs, and summer research programs like Project SEED.

TWO-YEAR COLLEGES

The nation's two-year colleges play an important role in providing access to careers in science, engineering, and technology, especially for students from groups currently underrepresented in the sciences. Two-year colleges provide the curricular paths for students who will transfer to baccalaureate programs in four-year colleges and universities. They also prepare technicians and technologists to assume active roles in research and development in industry, government, and academia.

I. Faculty Development

Faculties at two-year colleges have heavy teaching responsibilities that include lecture sections, laboratory teaching, and recitations. They need adequate time and opportunities for professional growth. Two-year college faculties need an understanding of both modern chemistry and new pedagogical techniques to ensure that students are exposed to the most stimulating and effective learning environments. Therefore, ACS supports:

- Making teaching responsibilities and working conditions in two-year colleges consistent with ACS guidelines for two-year programs.
- Providing two-year college chemistry teachers with ready access to professional development opportunities, including summer institutes, workshops, and conferences; weekend seminars; satellite broadcasts; and short courses. Faculties also need opportunities to develop networks and mentoring systems and to participate in faculty–faculty and faculty–industry exchanges.
- Establishing school/industry/government/ACS local section alliances to introduce current science information into the classroom and laboratory on a continuing basis. Such alliances could include sabbatical leave programs, industrial and government laboratory summer employment opportunities, and both formal and informal arrangements. The alliances should also participate in curriculum revision and development as well as implementation activities.
- Limiting the use of part-time or adjunct faculty in two-year colleges, but providing those faculty members with appropriate professional benefits as outlined in the *ACS Academic Professional Guidelines.*
- Allocating government and institutional resources to develop a dialogue, and establish cooperative activities, with faculty at other institutions of higher learning. Joint activities could involve fostering collaboration on research and demonstration grants, planning seminars, resolving articulation issues, and developing and implementing curricula.

II. Facilities and Instrumentation

Although some two-year colleges (especially those that offer chemistry-based technology programs) have the equipment and resources needed to provide outstanding instruction, many lack the necessary equipment and resources for modern laboratory-based instruction in chemistry. To ensure that all two-year institutions have the resources they need to teach chemistry, ACS recommends

- Expanding federal and state funding of instructional laboratory equipment and instrumentation, including faculty training, for two-year college chemistry programs. This will assist those institutions with a strong technology focus to maintain their state-of-the-art programs and help needy institutions upgrade equipment and instrumentation.
- Sharing resources and instrumentation locally through the establishment of alliances between two-year colleges and business, industry, and government, as well as between two-year and four-year colleges and high schools.
- Increasing the availability of funds to provide undergraduate instructional courses and research laboratories with modern equipment, maintain that equipment, and train faculty in their use and pedagogical applications.
- Increasing the resources available for faculty training so that they can acquire, adapt, maintain, and update educational technologies, including computers, CD-ROMs, and Internet access, for classroom and laboratory use. The appropriate use of educational technology should enhance, rather than supplant, the laboratory experience.
- Establishing and maintaining the growth of on-line library resources and information retrieval services, which will permit access to current developments in chemistry at all campuses within a given college system.
- Making funds available to needy institutions to support consultant review of their chemistry programs to improve chemistry instruction.

III. Curricula

Two-year colleges accommodate a large, diverse population of students who enter with varying educational backgrounds. As home to many "nontraditional" students, including older and working students, two-year colleges need to maintain flexible schedules and multiple levels of introductory chemistry. To meet the special needs of students in two-year colleges, ACS supports

- Developing, through consensus building, articulation agreements and other mechanisms at the local, regional, and statewide levels to facilitate the efficient transfer of students between two- and four-year institutions.
- Improving articulation between high schools and two-year colleges for both college-transfer courses and technician or other terminal degree programs. This can be best accomplished through local alliances, "tech prep" initiatives, and similar activities that help increase the level of mutual understanding between two-year colleges and secondary schools. It is critical that articulation ensure that students transferring from two-year colleges can compete effectively at the four-year college/university level.
- Using alternative approaches to teaching and appropriate assessment of introductory chemistry tailored to the specific needs of students, especially under-prepared students, groups underrepresented in the sciences, working students, older students, non-science majors, and students preparing for the technician fields. All such approaches must include a strong laboratory component as described in ACS *Guidelines for Chemistry in Two-Year Colleges*.
- Integrating into the laboratory curriculum concepts of environmental protection (including green chemistry) and laboratory safety.
- Integrating coverage of scientific ethics into the curriculum.

- Ensuring that continuing education courses for elementary and secondary school teachers provided by two- and four-year institutions are equivalent and receive similar recognition by the school districts.
- Developing programs of content review and pedagogy to involve mid-career and retired scientists in the service of science, engineering, and technology education (see also Secondary Schools).
- Providing programs to heighten the public understanding of science targeted not only toward students, but also toward the public at large.

IV. Undergraduate Research

Research can provide significant and stimulating experiences within the undergraduate curriculum and may influence career choices. To support a high-quality experience in the experimental component of the curricula at all levels, ACS recommends

- Expanding available funding for undergraduate research to summer as well as academic-year projects, to support the involvement of as many chemistry majors as possible in research, at as early a stage as feasible.
- Recognizing that creditable research can involve work other than classical laboratory projects, including, for example, research in chemistry education. This would be appropriate for those who already have a strong basis in the discipline and plan to pursue a career in teaching.
- Developing opportunities for undergraduate students to participate in external experiential research programs.

V. Underrepresented Populations

A number of groups are underrepresented in science, engineering, and technology careers. These include women, African Americans, Native Americans, Hispanics, and persons with disabilities. Proportionately more minorities are enrolled in two-year institutions than in four-year institutions. To ensure that all underrepresented groups have access to careers in science, engineering, and technology, ACS urges

- Targeting public funds to develop, within two-year colleges, model projects and activities designed to attract and retain students from underrepresented groups in the science disciplines. This will involve interactions with local pre-high and secondary school systems as well as four-year institutions, the wider public, and local business and industry.
- Developing incentives to foster the establishment of active partnerships between two-year colleges and surrounding schools, to identify at-risk youth, and to provide them with enrichment programs to facilitate their transfer into four-year institutions.
- Providing incentives to foster partnerships with employers for the training and retraining of the community's workforce.

FOUR-YEAR COLLEGES AND UNIVERSITIES

The study of chemistry is central to an understanding of the natural world and is essential for understanding a range of sciences other than classical chemistry and biochemistry. Advances in biotechnology, materials science, and engineering, as well as the applied sciences such as health care, nutrition, aviation, and environmental studies, have expanded the borders of chemistry. It has never been more important that chemistry be taken by all undergraduates to complete a liberal education or to begin a lifelong study. Thus, faculty must get involved in curriculum innovation that will excite and stimulate a broad spectrum of students, recognizing the importance of a multi-disciplinary approach to chemistry, the enabling science, while still maintaining the rigor of the discipline.

I. Faculty Development

Undergraduate faculty members need an understanding of both modern chemistry and new pedagogical techniques to ensure that students are exposed to the most stimulating and effective learning environments. Guidance and mentoring are an important aspect of the overall instructional mission. Institutional recognition and rewards for these kinds of professional activities must be a part of faculty evaluation. To encourage high-quality teaching in four-year colleges and universities, ACS supports

- Developing tangible institutional rewards for high-quality undergraduate instruction. Current rewards for instruction have too little impact on faculty prestige, particularly at research universities.
- Requiring professional development programs for teaching assistants and new faculty. These programs should include assignment of a mentor, frequent (at least quarterly) performance feedback from the appropriate senior faculty member(s), and preparation of a development plan. The focus should be on improvement and development rather than weeding out.
- Providing support, through institutional and outside funding, for continuing faculty development, including appropriate professional development for temporary, adjunct, and part-time faculty. This should include providing faculty with the tools necessary to address assessment issues related to student learning outcomes, faculty effectiveness, and the curriculum.
- Developing policies to promote a balance between teaching and research activities, including research in chemistry education. Possible programs include the funding of joint research and teaching activities, or supporting young scholar-educators as post-doctoral students and new faculty members.
- Providing opportunities for faculty development in industry and in government agencies, and integrating those experiences into the curriculum. Since the majority of baccalaureate and doctoral students will be employed by industry, faculty need a broad exposure to chemistry in an industrial setting to prepare their students for the workplace.
- Ensuring that those part-time, adjunct, and temporary faculty members receive reasonable compensation, including benefits outlined in the *ACS Academic Professional Guidelines* and opportunities to participate in activities that foster continued professional growth.

II. Curricula

Curricula must be thoughtfully designed for the intended audience of students, which may include chemistry majors, other science majors, applied science majors, or non-science majors. The course content must reflect the breadth and vitality of chemistry——the central and enabling science. The pedagogy employed must utilize knowledge from cognitive science research on how students best learn chemistry. To support high-quality curricula in colleges and universities, ACS recommends

- Adopting the most appropriate pedagogical and assessment techniques to enhance and evaluate student learning.
- Modifying and developing current courses to reflect modern chemistry and cutting-edge developments in our broadening discipline. This should include industrial and business components within courses since most chemistry graduates will enter business and industry.
- Reflecting the interdisciplinary character of chemistry within all courses, as the centrality of chemistry provides a valuable basis for understanding other areas of study.
- Integrating oral, written, and other appropriate methods of communication, as well as information management and retrieval technologies into all aspects of the curricula.
- Integrating within the laboratory component concepts of environmental protection (including green chemistry) and laboratory safety.
- Integrating coverage of scientific ethics into the curriculum.

- Developing courses for non-science majors, strong in content and high in appeal to the non-major, to reflect the relevance of science to solving social problems, and the science knowledge needs of the general population.
- Developing degree programs in chemistry for those who will become pre-college teachers. Teachers in the K–12 sector must be educated in both basic science principles and pedagogy. A well-designed chemistry education program would permit students to acquire the necessary science and educational background within a four-year degree program. The ACS Committee on Professional Training has defined one such program through its offering of an ACS-approved degree in chemistry/chemistry education, and now also offers a minor in chemistry education.
- Ensuring that students' course articulation between two- and four-year colleges can be accomplished with a minimum of disruption and time loss, and without sacrificing academic credit.
- Developing asynchronous programs, for example, Internet-based distance learning) to serve those unable to participate in regular campus courses. Education must be available to those who wish to benefit from it, even when they are not able to attend a traditional college campus.
- Providing funding to faculty for curricular development, implementation, and assessment.

III. Facilities and Instrumentation

New or remodeled facilities provide the basis for the most effective learning, which includes modern technology and the latest in safety considerations. Modern instrumentation is required to expose students to the methods and equipment that they will use as working chemists and to carry out meaningful undergraduate laboratory research. To ensure the necessary physical infrastructure for modern chemistry instruction, ACS supports

- Increasing funds for the construction of new, and remodeling of existing, chemistry facilities.
- Increasing the availability of funds to provide undergraduate instructional courses and research laboratories with modern equipment, maintain that equipment, and train faculty in their use and pedagogical applications.
- Designing new laboratory experiences that include the use of appropriate instrumentation, even at the freshman level. While it is important to use sophisticated instrumentation relevant to the instructional goals of a given laboratory course, the development and use of cost-effective instrumentation may also be pedagogically sound.
- Including the use of modern computer equipment and appropriate Internet access in the lecture and laboratory curricula. Computer simulation of experimentation must be used as a supplement to and extension of, not as a replacement for, hands-on experiences in chemistry.
- Developing partnerships between colleges and local industry, government, and other organizations to maximize utilization and availability of sophisticated instrumentation.

IV. Undergraduate Research and Experiential Learning Opportunities

Research can provide significant and stimulating experiences within the undergraduate curriculum and may influence career choices. To support a high-quality experience in the experimental component of the curricula at all levels, ACS recommends

- Expanding available funding for undergraduate research to summer as well as academic-year projects, to support the involvement of as many chemistry majors as possible in research, at as early a stage as feasible.
- Developing programs that allow majors in other sciences and non-science majors to experience first-hand research in the chemical sciences.
- Recognizing that creditable research can involve work other than classical laboratory projects, including, for example, research in chemistry education. This would be appropriate for those who already have a strong basis in the discipline and plan to pursue a career in teaching.

- Developing opportunities for undergraduate students to participate in external experiential research programs, as well as the understanding by students that this is a valuable and important part of their educational experience.

V. Underrepresented Populations

A major resource of our country is the talent of our citizens. Every effort must be made to encourage and provide opportunities for the education of all those who are qualified and willing to benefit from this experience. To support the maximum use of our personnel resources, ACS recommends

- Developing and supporting programs designed to attract and retain women, African Americans, Native Americans, Hispanics, and disabled students into undergraduate programs in chemistry. Many in these groups are unaware of career options in chemistry and of funding opportunities for undergraduate and graduate study in chemistry.
- Providing connections for these students to work with the community and local schools to bring the message of the excitement of science and career opportunities to their populations.
- Providing guidance and support for newly hired faculty from underrepresented groups. These faculty members are often under special pressure in their early academic years since they are often serving as mentors themselves.

POST BACCALAUREATE EDUCATION

Post baccalaureate (graduate) education in the chemical sciences includes the doctoral and master's level of formal education and, for some, a subsequent postdoctoral experience. There is strong support that graduate education, particularly at the doctoral level, continues to stress original research as the basis of the graduate experience. In addition to the problem-solving skills students develop through focused research, they should be encouraged to recognize the broader applicability of these skills, particularly with respect to the interdisciplinarity of science, and topics such as economics, management, ethics, and oral and written communication. Mentoring by the graduate faculty must be an integral part of the education sequence. Recruiting to attract and retain underrepresented populations will provide the broadest possible resource of professional chemists. The diverse objectives of programs at the post-baccalaureate level call for caution in prescribing educational practices, but with this caveat, the ACS recommends

- Ensuring that graduate education at the doctoral level continue to provide students with the opportunity to engage in creative research, pure or applied, in the chemical sciences.
- Broadening the graduate experience to include more specific training in, for example, communication, ethics, safety, and functioning in team and multidisciplinary projects.
- Providing mentoring and career guidance programs for students throughout their graduate experience.
- Expanding funding for graduate student support through traineeships and fellowships, in addition to direct faculty research funding.
- Developing special programs to recruit and retain underrepresented minorities and women in graduate school.
- Encouraging federal and state support to improve the infrastructure for graduate chemistry education through grants for instrumentation, as well as funds for building new, and remodeling existing, facilities.
- Providing incentives for industry to contribute research support to colleges and universities and to develop university–industry research partnerships. The participation of industry in graduate education can enhance the interactions between these two sectors and provide enhanced employment opportunities for students.
- Recognizing that a variety of approaches to research support can encourage greater creativity, a healthy balance between individual investigator grants, small and large group grants, and research centers should be maintained.

- Developing opportunities for graduate students to participate in external experiential programs in government and industry.
- Developing opportunities that include appropriate pedagogical components and practice for those students who will become college and university faculty.
- Promoting programs for professional master's degrees, including professional degrees such as for those who are, or will become, teachers.
- Ensuring that graduate teaching assistants and postdoctoral fellows are accorded appropriate compensation and recognition as outlined in *ACS Academic Professional Guidelines*.

CONTINUING EDUCATION

The strong technology base of the United States economy depends on the continuing education of its entire workforce, including those currently underrepresented in chemistry such as women, African Americans, Native Americans, Hispanics, and persons with disabilities. ACS recommends

- Establishing tax incentives to encourage individuals to enhance their technical competence through continuing education.
- Developing and supporting programs to reach segments of the workforce that do not have access to classical education institutions. This might include developing courses and instruction at industrial sites or finding other ways to reach a broad audience.
- Tailoring the content and scheduling of appropriate chemistry courses to the continuing education needs of the local workforce.
- Encouraging the direct participation of the industrial sector in continuing education in chemistry.
- Designing programs to retrain individuals whose livelihoods have been disrupted by the economic restructuring and outsourcing of business and industry.