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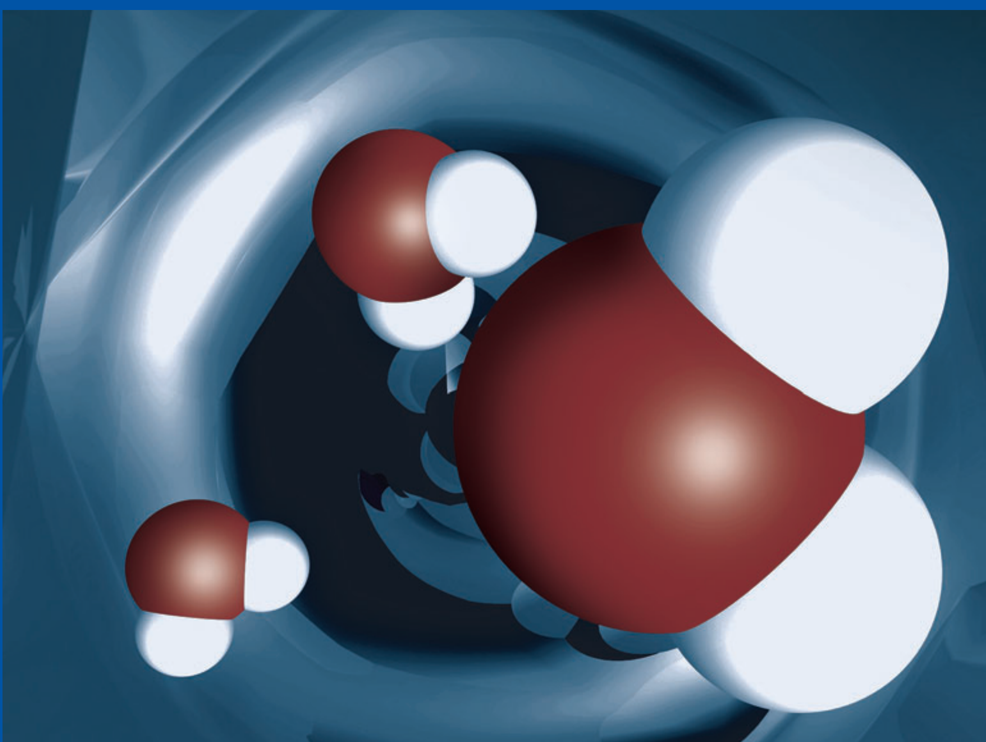
ACS Guidelines for Chemistry in Two-Year College Programs



Fall 2015

American Chemical Society

Society Committee on Education

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An electronic version of the ACS Guidelines for Chemistry in Two-Year College Programs *and additional information are available at www.acs.org/2YGuidelines.*

Disclaimer:

The following guidelines have been prepared with the objective of improving the standards and quality of chemistry education in two-year college programs. They have been developed from sources believed to be reliable and to represent what are believed to be the most knowledgeable viewpoints available with regard to chemistry education. No warranty, guarantee, or other form of representation is made by the American Chemical Society (ACS) or by the ACS Committee on Education (the "Committee") or by any of the Committee's members with respect to these guidelines and their use. ACS and the Committee hereby expressly disclaim any and all responsibility and liability with respect to the use of these guidelines for any purposes. This disclaimer applies to any liability that is or may be incurred by or on behalf of the institutions that adopt these guidelines; the faculties, students, or prospective students of those institutions; and any member of the public at large; and includes, but is not limited to, a full disclaimer as to any liability that may be incurred with respect to possible inadequate safety procedures taken by any institution.

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ACS GUIDELINES FOR CHEMISTRY IN TWO-YEAR COLLEGE PROGRAMS

1. Goals of the ACS Guidelines

Chemistry is central to intellectual and technological advances in many areas of science. The traditional boundaries among chemistry subdisciplines are blurring, and chemistry is increasingly intersecting with other sciences. Unchanged, however, is the atomic and molecular perspective that lies at the heart of chemistry. Chemistry-based programs have the responsibility to communicate this outlook to their students and to teach the skills their students need to apply it.

Chemistry taught in two-year college programs can be divided into three categories:

- **Chemistry transfer programs**: These are primarily intended to prepare students for baccalaureate chemistry programs and may or may not culminate in an associate of science (A.S.) or equivalent degree.
- **Chemistry-based technology programs:** These are primarily intended to prepare students for the workforce and usually culminate in an associate of applied science (A.A.S.) or equivalent degree.
- **Chemistry-based courses that support programs in other disciplines:** These are chemistry courses that may or may not be part of a dedicated chemistry program but are integral to the education of students in other programs.

ACS has developed this set of guidelines to promote high-quality chemistry education for students in all types of two-year college programs. The goal of these guidelines is to help faculty provide students with the best possible education in the fundamental areas of modern chemistry while relating it to other disciplines and to society.

ACS recognizes that the diversity of institutions and students is a strength in higher education. Thus, the *ACS Guidelines for Chemistry in Two-Year College Programs* were developed to provide a comprehensive model designed for a range of institutions that offer chemistry education in the categories described above. Regardless of individual program goals, all benefit from an energetic and accomplished faculty, a modern and well-maintained infrastructure, and a coherent chemistry-based curriculum that develops content knowledge and broader skills through the use of effective pedagogical approaches.

Although a program may not fulfill all of the guidelines, it will benefit from pursuing those appropriate for its mission, student body, and curriculum. Implementing the ACS guidelines can ensure that the chemistry course offerings and programs of an institution:

- Are consistent with the mission of the institution
- Meet the needs of the diverse backgrounds and abilities of entering students
- Enhance the strengths of the institution and the community
- Articulate with programs to which students transfer
- Enable students to graduate with skills necessary to enter the workforce
- Are comparable to programs of recognized quality
- Augment continuing education and other local community chemistry education needs
- Support a safe environment for teaching and learning

Educators must prepare students to make informed decisions about a wide variety of scientific issues. The ACS guidelines apply not only to students pursuing careers in scientific fields, but also to chemistry students pursuing other careers.

The ACS guidelines provide a framework for reviewing two-year college chemistry programs, identifying areas of strength and opportunities for change, and leveraging support from institutions, partners, and external agencies. In preparing and disseminating these guidelines, ACS seeks to enhance understanding of the many different two-year college environments and to engage chemistry faculty and programs across higher education in efforts to address needs, support resource development, and foster excellence.

2. Institutional Environment

Effective chemistry education requires a substantial institutional commitment to an environment that supports long-term excellence. Existing within the context of the institutional mission, a two-year college chemistry program must support the needs, career goals, and interests of the institution's students.

In order to support viable and sustainable chemistry-based education, the institutional environment must provide and develop the following attributes.

2.1 Institutional accreditation. The institution must be accredited by the regional accrediting body. Such accreditation ensures broad institutional support in areas such as mathematics, related sciences, and the humanities. During institutional reviews, these guidelines should be consulted as part of self-studies and shared with the accrediting bodies.

2.2 Program organization. The administration of the program must reside in an appropriate department that includes full-time faculty members with advanced chemistry degrees. The department must have an adequate budget and significant influence over faculty selection and promotion, curriculum development, and assignment of teaching responsibilities. Departmental input regarding allotment of office, classroom, laboratory, and other spaces must be solicited. If part of a larger unit, the chemistry faculty must have substantive autonomy over the functions relating to the chemistry courses.

2.3 Faculty policies. The institution must support faculty efforts to develop high-quality instructional programs. The institution's policies regarding salaries, teaching loads, promotions, tenure and/or continuing contracts, leave policies (including sabbaticals), and hiring practices must be developed with faculty input, encourage improved faculty morale, and serve to attract and retain high-quality chemistry faculty members. Recognition programs should be in place to foster and reward significant contributions and innovations by faculty, as a group or individually.

2.4 Program budget. Robust chemistry-based education requires continuing and stable financial support. The institution must have the ability and desire to make a sustained commitment to the program at a level that is consistent with the resources of the institution and its educational mission. Adequate support enables a program to provide:

- Qualified faculty with the scientific breadth to offer the courses and educational experiences described in these guidelines
- Nonacademic staff and resources for administrative support services, stockroom operation, and instrument and equipment maintenance

- Physical plant meeting modern safety standards with appropriate chemical storage, waste-handling, and disposal facilities
- Sufficient budgets to cover the costs of teaching a laboratory-based discipline
- Resources for capital equipment acquisition, long-term maintenance, and expendable supplies to ensure that equipment remains useful throughout its lifetime
- Support for maintaining and updating instructional technology
- Modern chemical information resources appropriate for the breadth and depth of courses offered
- Services to support student learning
- Opportunities for professional development for the faculty, including sabbatical leaves
- Funds and support to encourage faculty members to attend professional meetings and promote scholarly growth
- Resources to support faculty-mentored research as appropriate to the institutional mission
- Personnel support to assist with the acquisition and administration of external funding

2.5 Safety culture. A strong safety culture protects faculty, students, and staff; promotes a sense of confidence among employees and students; and allows everyone on campus to focus on their work. Academic administrators, faculty members, and staff have an ethical responsibility to ensure students' safety, to teach students safety skills, and to make sure students acquire the proper knowledge of safety principles.

Organizations in which leaders demonstrate a commitment to overall safety, rather than mere regulatory compliance, have been shown to have the lowest injury rates.[1] A strong safety culture requires the highest level of leadership (i.e., the president or chancellor) to demonstrate an active commitment to safety and establish a policy that addresses safety and assigns responsibilities for its maintenance throughout the institution. Those at the next level of leadership, such as vice presidents or provosts, provide oversight for the implementation of the safety policy and a safety program. Deans, directors, and chairs are assigned responsibilities for implementing

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1 ACS Committee on Chemical Safety. *Creating Safety Cultures in Academic Institutions: A Report of the Safety Culture Task Force of the ACS Committee on Chemical Safety;* American Chemical Society: Washington, DC, 2012.

the safety program in their areas. Faculty and staff are responsible for the safety of their colleagues and students and for ensuring that safety skills are integrated throughout the curriculum.

3. Faculty and Staff

Providing current and effective chemistry education requires an engaged and accomplished faculty. The chemistry faculty are responsible for defining the overall goals of the program (as appropriate), facilitating student learning of curriculum content, developing students' professional skills, and modernizing the curriculum as the discipline evolves. Therefore, mechanisms must be in place to maintain the professional competence of faculty members, to provide faculty development and mentoring, and to allow for regular feedback regarding faculty performance. Similar mechanisms are needed for instructional and support staff.

3.1 Faculty. The chemistry faculty should have the range of educational backgrounds, the expertise, and the commitment to provide a sustainable, robust, and engaging environment for student learning. Everyone who teaches chemistry courses that result in a grade on a college transcript from the institution, regardless of location or mode of delivery, is considered part of the chemistry faculty and must meet institutional standards.

The chemistry faculty should have the following attributes:

- The minimum academic preparation required of any chemistry faculty member is a master's degree in a discipline of chemistry. The ability to communicate an understanding and appreciation of chemistry to others is essential. Further academic training (a doctoral or second master's degree in a related field) is highly desirable, particularly if it stresses depth and breadth of knowledge in chemistry.
- Full-time, permanent faculty should be sufficient in number to teach the full range of courses on a regular basis, with the number of credit hours taught by permanent faculty exceeding 75% of the total chemistry offerings.
- The collective expertise of the faculty should reflect the breadth of the major areas of modern chemistry. If an institution has a mission that more narrowly defines its programs, the faculty expertise may reflect that focus.

The department's climate and institutional policies should foster the development of a faculty with a wide range of backgrounds and experiences who can serve as role models for student bodies that are diverse in gender, ethnicity, race, and disability status.

The *ACS Academic Professional Guidelines*,[2] which describe responsibilities of students, faculty, and administration, should be followed. The institution should also comply with the *1940 Statement of Principles on Academic Freedom and Tenure.*[3]

3.2 Adjunct, temporary, and part-time faculty. Qualified individuals outside the full-time, permanent faculty should only be used to provide specific expertise and/or accommodate temporary term-to-term fluctuations in enrollments. While use of adjunct faculty to provide insight into current workplace practices can be valuable, a dedicated core of chemical education experts (i.e., permanent faculty) is needed to provide stable, consistent, and robust chemistry education. Thus, excessive reliance on adjunct faculty is discouraged.

Any adjunct faculty should be given compensation and professional development opportunities equivalent to those of full-time, permanent faculty. Adjunct faculty should have access to facilities that support class preparation, confidential discussions, and other teaching activities. Adjunct faculty should have the opportunity to be integrated into college activities and be given consideration for permanent positions. Courses taught by adjunct faculty should be aligned, in curriculum and content, with those of full-time faculty. Student learning in courses taught by adjunct faculty should be evaluated to ensure it is comparable to that in courses taught by permanent faculty.

3.3 Teaching contact hours. Contact hours are defined as the actual time spent in the direct supervision of students in a classroom (face-to-face or online) or laboratory. Online activities that are developed as substitutes for classroom instruction should be assigned the same contact hour value as

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2 American Chemical Society. *Academic Professional Guidelin*es [Online], 4th ed.; American Chemical Society: Washington, DC, 2008. http://www.acs.org/content/acs/en/careers/career-services/ethics/academic-professional-guidelines.html (accessed Sept 10, 2015)

3 American Association of University *Professors. 1940 Statement of Principles on Academic Freedom and Tenure, in Policy Documents and Reports* 3; American Association of University Professors: Washington, DC, 1984. http://www.aaup.org/report/1940-statement-principles-academic-freedom-and-tenure (accessed Sept 10, 2015)

equivalent face-to-face experiences. Additionally, each laboratory contact hour should be assigned the same contact hour value as a classroom contact hour.

The total number of contact hours in classroom and laboratory instruction for faculty or instructional staff members *should not exceed 15 total hours per week*; an instructor should carry no more than 450 student contact hours[4] per week. If necessary, teaching loads as high as 18 hours per week may be assigned, provided that the average teaching load for all chemistry faculty does not exceed 15 hours per week for the academic year, and that the higher teaching load is only in effect for one term in that academic year.

Teaching assignments that exceed this standard risk lowering the quality of chemistry education and the academic institution. Fifteen contact hours is an upper limit; a smaller number should be the normal teaching obligation. Faculty and instructional staff members in the most effective programs usually have substantially fewer contact hours, particularly when they supervise student research projects or assume administrative or support activities.

Faculty members, after fulfilling teaching obligations, must have adequate time for the following professional activities:

- Holding office hours to meet with students
- Fulfilling service responsibilities to the department, the campus, and the community
- Developing new courses and curriculum innovations
- Assessing and improving curriculum
- Keeping abreast of new developments in chemistry and new educational pedagogies
- Participating in professional activities, including conferences
- Engaging in scholarship in chemistry, chemistry education, and teaching effectiveness.

No faculty member should be responsible for more than 25 students in a laboratory at one time.[5] Many laboratories require smaller numbers for

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4 Student contact hours equal the number of individual students taught, multiplied by the number of hours spent with the students in classroom and lab.

5 American Chemical Society. *Safety in Academic Chemistry Laboratories; Vol. 2, Accident Prevention for Faculty and Administrators,* 7th ed.; American Chemical Society: Washington, DC; 2003.

safe and effective instruction (e.g., 20 students is the recommended maximum for an organic chemistry laboratory).

3.4 Professional development. Sound policies regarding salaries, duties, promotions, sabbatical leaves, and tenure are essential. Institutional policies and practices should provide opportunities and resources for scholarly activities that allow faculty and instructional staff members to stay current in their specialties and modern pedagogy in order to teach most effectively. Faculty members should also be encouraged to seek professional development opportunities through teaching and learning centers and program partners and to develop new pedagogical initiatives.

- Institutions should provide opportunities and adequate funding for renewal and professional development through sabbaticals, participation in professional meetings, and other professional activities. Institutions should provide resources to ensure program continuity during sabbaticals and other leaves. Faculty should use these opportunities to keep current in their fields, to advance their skills, and to make valuable connections with chemical professionals from industry and government.
- Excellent institutions offer mechanisms by which faculty members are mentored. Proper mentoring integrates each member of the instructional staff into the culture of his or her particular academic unit and institution, and into the chemistry profession, ensuring the stability and vitality of the program.
- Faculty should have opportunities for externships, job shadowing, and other workplace experiences with their program partners or other businesses. This is especially important in chemistry-based technology programs, as such experiences strengthen the faculty's knowledge and skill in preparing students for the workplace.

In addition to supporting scholarly activities, the institution should provide regular training in the areas of safety, technology, and assessment.

3.5 Support staff. A sustainable and robust program requires an adequate number of secretarial, administrative, and support personnel, along with technical staff to maintain chemical inventories and instrumentation, support laboratory functions, and assure regulatory and safety compliance. The number of support staff members should be sufficient to allow faculty to devote their time and effort to academic responsibilities and scholarly activities. One full-time laboratory technician for every four full-time or full-time-equivalent chemistry faculty members is recommended. Part-time and student help are not adequate substitutes for full-time laboratory technicians.

Two-year colleges must have a chemical hygiene officer with appropriate training and experience to develop, manage, and implement the chemical hygiene plan for the campus.[6] Colleges may also have a dedicated safety position responsible specifically for the chemistry or science department, as appropriate. In order to ensure consistent implementation of safety policies, it is recommended that the duties of a chemical hygiene officer be assigned to a dedicated, full-time position, rather than added to the teaching duties of the faculty.

Many two-year colleges have an Environmental Health & Safety (EHS) department or committee that includes the chemical hygiene officer. The purpose of the EHS group is to manage the campus safety program, support consistent implementation of safety policies, maintain the chemical hygiene plan, and ensure all faculty, staff, and students have up-to-date safety training.

To foster the development of a safe environment and a safety-conscious culture, all technical staff members, including part-time and student help, should receive regular training in chemical safety protocols, proper use of equipment, and waste management.

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6 Occupational exposure to hazardous chemicals in laboratories. *Occupational Safety and Health Standards,* Standard no. 1910.1450, 1990. https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10106 (accessed Sept 10, 2015)

4. Infrastructure

A modern infrastructure is essential for effective and rigorous chemistry-based education. Institutional support for program infrastructure is needed for sustainability through inevitable fluctuations in faculty, leadership, and funding levels.

4.1 Organization of facilities. A program must have appropriate classroom, laboratory, other instructional, office, and common space that is safe, well-equipped, modern, and properly maintained. Laboratory and stockroom space must conform to applicable government standards and regulations. In addition:

- Chemistry classrooms should be reasonably close to instructional and research laboratories. Classrooms should adhere to modern standards for lighting, ventilation, and comfort and have proper demonstration facilities, projection capabilities, and Internet access. Classrooms should be flexible learning spaces that are able to accommodate new pedagogies.
- Faculty offices should be configured for instructional and other professional activities. They should also accommodate confidential discussions with students and colleagues. Offices should have networked computers that provide access to library resources. Faculty offices should be reasonably close to teaching and laboratory facilities and positioned to facilitate student contact. Adjunct faculty members should have comparable offices.
- Laboratories must have properly functioning utilities, fume hoods, safety showers, eyewashes, first aid kits, and fire extinguishers.
- Laboratory capacities should not exceed 25 students.[5]
- Laboratories should be designed to provide at least 50 square feet of net space per student, including lab tables and benches.[7]
- Laboratory facilities must be able to accommodate students with disabilities in accordance with federal and state regulations.
- A properly maintained chemical stockroom should be in the vicinity of teaching and research space. The stockroom must provide safe storage, handling, and preparation areas and permit easy distribution of chemicals to required areas.

7 National Fire Protection Association. NFPA 101: *Life Safety Code*, 2015. http://www.nfpa.org/codes-and-standards/document-information-pages?mode=code&code=101 (accessed Sept 10, 2015)

- Laboratories should have facilities appropriate for the type of work conducted in them. These facilities should permit maintaining experimental arrangements for extended periods of time during ongoing research projects.

The infrastructure for chemistry-based technology associate degree programs is determined, in part, by the needs of the employers. As with other types of programs, the personnel, facilities, and equipment should be sufficient to meet the goals of the program. With chemistry-based technology degree programs, the program partners are sometimes able to provide some of the needed infrastructure.

4.2 Equipment and instrumentation. Programs should have a suite of modern chemical instrumentation and specialized laboratory apparatus appropriate for the courses offered, providing hands-on laboratory experiences in synthesis, characterization, and analysis.

- Programs must have certain essential equipment, such as electronic balances, volumetric glassware, pH meters, colorimeters, thermometers or temperature probes, hot plates and/or Bunsen burners, and filtration equipment.
- Standard items, such as automated data collection devices with associated probes, bench-top centrifuges, melting point apparatus, microscale or full-scale organic kits, gas chromatographs, and UV-vis spectrometers, are highly recommended for programs serving students pursuing careers in science or health.
- Students pursuing chemistry careers should have access to standard chemistry instrumentation, such as FTIR, FT-NMR, and mass spectrometers, etc. If on-site instrumentation does not meet students' educational needs, stable arrangements should be made with proximal sites to provide ready access to the appropriate instruments.

Chemical instrumentation is an evolving area of chemistry. Faculty members should have opportunities to keep abreast of changes and improve the program's instrumentation.

Because chemistry-based technology programs typically must provide a broader range of hands-on experiences, these programs usually need more equipment and laboratory space than transfer and support programs.

Depending on the focus of the program, specialty equipment may be needed; for example, a process technology program may need a pilot plant, but a biotechnology program may need gel electrophoresis equipment. There should be sufficient equipment for all students in the program, space for the equipment, and personnel to maintain the equipment.

4.3 Computer technology and software. Students should have access to computing facilities and software that support laboratory data acquisition and analysis, interactive simulations, and computational chemistry. Software with scientific word processing and illustration capabilities should be available.

4.4 Chemical information resources. Both faculty and students should have access to the chemical literature. Physical and electronic repositories should include current chemistry and related science periodicals and peer-reviewed journals, scientific databases, and other appropriate reference materials, commensurate with the size and nature of the chemistry offerings and the scholarly activity of the students and faculty. Important reference materials, or electronic access to these materials, should be within or near the chemistry facilities and accommodate the following considerations:

- The chemical literature continues to expand at a rapid rate. The library should provide access to journal articles that are not readily available on-site by supplying other mechanisms, such as interlibrary loan, electronic transmission, or document delivery services.
- Instruction regarding the use of information from the chemical literature should be equivalent to that in the institutions to which students commonly transfer. Trained science librarians should be involved in the design and facilitation of these activities.

4.5 Chemical safety resources. The program must be conducted in a safe environment with adherence to federal, state, and local regulations regarding chemical storage, hazardous waste management, and laboratory safety.

The following are required by federal law;[8] there may be additional federal, state, and local requirements:

- A written chemical hygiene plan consistent with U.S. Occupational Safety and Health Administration (OSHA) and state standards, as well as a mechanism for aligning this plan with all teaching and any research activities
- Personnel designated to coordinate all aspects of the chemical safety program in cooperation with institutional and other departmental safety programs
- Regularly tested and inspected eyewashes, shower stations, and fire extinguishers in all areas where such safety equipment is mandated
- Training for all laboratory personnel in the appropriate use of personal protective equipment and all safety equipment available onsite
- Segregated storage areas designated for acids, bases, reducing agents, oxidizing agents, and toxic materials. Cabinets and refrigerators that store flammable materials must meet the OSHA and other appropriate federal and state regulations. National Fire Protection Association (NFPA) and Globally Harmonized System (GHS) labeling codes must be used on all reagents and storage facilities.

The following are recommended practices that support a safe learning and working environment:

- Proper facilities and personnel for chemical waste disposal aligned with OSHA and state regulations
- Laboratory safety plans that recognize the specific hazards encountered in chemistry laboratories
- Standard operating procedures (SOPs) for the storage, use, and disposal of any particularly hazardous materials
- Safety information and reference materials, such as safety data sheets (SDSs), and personal protective equipment readily available to all students and faculty

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8 Occupational exposure to hazardous chemicals in laboratories. *Occupational Safety and Health Standards*, Standard no. 1910.1450, 1990. https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10106 (accessed Sept 10, 2015). Also, Fire Protection. *Occupational Safety and Health Standards*, Standard no. 1910.157; U.S. Department of Labor, 2012. https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9811 (accessed Sept 10, 2015). See also, The Uniform Fire Code (UFC) Section 80.301 (n) and the National Fire Protection Association (NFPA) comments following section 4-3.1.

- A policy regarding maximum stockroom chemical holdings, including small quantities for especially hazardous materials
- Personal protective equipment available to all faculty, staff, students, and visitors
- Optional safety equipment, aside from the federally mandated eyewashes, shower stations, and fire extinguishers, that is inspected and maintained as appropriate
- Regularly tested and inspected fume hoods in all laboratories that involve the use of volatile or potentially hazardous materials
- Regular inspections of all laboratories and systematic review of safety protocols and procedures. Safety incident reporting system accessible by all faculty, staff, and students: Incidents should be reported within 24–48 hours, and close calls and nonreportable incidents should be included.
- Safety incident investigation system to collect reports, investigate incidents, and report effective practices and lessons learned to all faculty, staff, and students. Investigations should be considered learning opportunities, and information should be shared freely without fear of retaliation.[9]
- Safety incident database that contains information about safety incidents, investigations, near misses, and nonreportable incidents—this database should be used to identify trends, address challenges, and highlight effective practices.

4.6 Student support services. An institution must have support services in place to help students move toward attaining their goals. Student support services must be appropriate for the student body and be consistent with the institutional mission. Support services should include:

- Advising staff who work with the faculty to enable students to achieve their academic goals
- Staff specialized in helping students with career and transfer resources
- Academic and personal support for students with physical, communication, learning, and other disabilities

9 While egregious incidents may result in punitive action, it should be noted that OSHA prohibits retaliation for reporting safety issues. OSH Act of 1970, Section 11 (c) https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=OSHACT&p_id=3365 Moreover, punitive action will drive faculty and staff to stop reporting incidents.

- Tutorial services for students to improve their study skills and become more effective learners
- Open and reliable access to technology, such as computers
- Programs and organizations to support and engage targeted communities of students, such as student clubs
- Programs that increase the participation of underrepresented groups
- Assistance for students in acquiring financial aid

4.7 Transferring students. Faculty, counselors, and advisers from two-year chemistry programs should be in regular communication with their counterparts at institutions that accept a significant number of transfer students to ensure that the curricula of both institutions are appropriately coordinated. Two-year programs should convey the educational backgrounds and academic goals of their students to the receiving institutions. Both transferring and receiving institutions should assist students in making a successful transition.

Although specific courses are most commonly articulated by two-year and four-year institutions, it is recommended that program articulation be used, as appropriate, to better serve students. All transferring students, including chemistry-based technology students, should be counseled to take the full general chemistry course sequence, full organic chemistry course sequence (if appropriate), cognate mathematics and physics courses, and general education courses in patterns comparable to the course work of freshmen and sophomores at the institutions to which the students plan to transfer.

In addition, mentoring and other types of academic support should be provided to help students prepare for the challenges inherent in transferring to new programs and environments. Support can be offered in a variety of forms including, but not limited to, transfer-specific orientation workshops, bridge classes, transfer success courses, peer mentoring, leadership retreats, field trips, student clubs, and ACS student chapters.

5. Curriculum

An effective chemistry curriculum is driven by the needs of the students, the mission of the institution and the program, the standards of the discipline, and the needs of the partners. Partners representing key stakeholders (see Section 10) should participate in curriculum development to ensure that key skills and knowledge are addressed. For example, local employers should provide input for chemistry-based technology programs, and four-year institutions should provide feedback for transfer programs.

Recognizing that these may change over time, the curriculum should reflect two specific areas of need: (1) students who require education in the scientific method but do not require a significant amount of science for their ultimate academic and career goals, and (2) students for whom chemistry will be a substantial part of their academic path. This latter group includes students in allied health and all other health science fields, as well as those in science, technology, and engineering fields. Education majors may fall in either group, as appropriate for local certification. Courses should support the curriculum goals and be offered with sufficient frequency to enable a qualified student to complete the program in two years.

Common courses can serve multiple programs, or courses can be developed specifically for chemistry transfer, chemistry-based technology, or other programs. Courses intended to support student transfer to an ACS-approved baccalaureate chemistry program should provide a foundation in the traditional subdisciplines of chemistry (analytical, biochemistry, inorganic, organic, and physical) and address the unique chemistries of both small molecules and macromolecules, such as polymers, biological molecules, and nanoscale systems.

5.1 Pedagogy. Sound pedagogy informed by research on student learning is the cornerstone of an effective chemistry curriculum. The institution must regularly review its chemistry program to ensure that it provides excellent content with good pedagogy and builds skills that students need to be effective and valuable professionals.

Courses should be taught in a challenging, engaging, and inclusive manner that accommodates a variety of learning styles. Current examples of effective pedagogy include problem- or inquiry-based learning, peer-led instruction, group learning, learning communities or networks, writing throughout the curriculum, and technology-aided instruction. Faculty members must be provided with opportunities to maintain their knowledge of best practices in chemistry pedagogy and modern theories of learning and cognition.

As an experimental science, chemistry must be taught using appropriate and substantial laboratory work that promotes independent thinking, critical thinking and reasoning, and a perspective of chemistry as a scientific process of discovery. While they may require additional faculty preparation, inquiry-based and open-ended investigations are particularly well-suited for this type of laboratory work.

5.2 Online and virtual instruction. Classes taught partially or wholly online should provide at least the same skill development and content as the corresponding, wholly face-to-face experience. Colleges should ensure that students in such courses have adequate access to faculty and instructors and opportunities for collaboration with peers. Faculty contact-hour credit for virtual and online instruction should be equivalent to the corresponding classroom experience.

Chemistry is an empirical science that requires the safe and effective physical manipulation of materials, equipment, and instrumentation. This hands-on expertise cannot be developed through virtual laboratory exercises. Virtual and computer-simulated labs may supplement hands-on laboratory exercises, but they must not replace them (see also Section 5.14).

5.3 Prerequisites. The diversity in the educational background, learning readiness, academic ability, and educational goals of students must be considered in curriculum development. The institution must accept that all students are not prepared to begin chemistry at the same level and that all programs requiring chemistry do not cover identical topics. The prerequisites for each chemistry course should be carefully determined, in consultation with colleagues at other institutions if appropriate, and assessed by the faculty. Prerequisites should be clearly stated and publicized in the college catalogues, in the schedule of classes, and in any other curriculum publications.

Students are best served when everyone involved in student admission to chemistry classes respects the importance of adhering to prerequisites. Failure to do so reduces student retention and graduation rates, as well as the quality of the learning environment. An effective assessment of each student's preparation and readiness for a course can be achieved by testing, transcript evaluation, and/or counseling. Students who do not have the prerequisites for a given chemistry course should be redirected to the necessary preparatory course(s) in chemistry, mathematics, and/or other developmental skills.

5.4 Consistency of course offerings. Content and learning outcomes of a course should be monitored to ensure a consistent level of academic rigor. All sections of a course that result in a grade on an official transcript from the institution, regardless of location or mode of delivery, must be taught by qualified faculty members and use course materials with similar coverage and levels of difficulty.

5.5 Dual enrollment and early admission courses. A variety of options have been implemented at two-year colleges for enabling students to receive college credit while still enrolled in high school. High school students may be enrolled in college courses directly, or college courses may be offered at high schools or on the college campus; courses may be taught by high school or college faculty. Regardless of the precise mechanism, such courses can foster and sustain essential collaborations between area high schools and institutions of higher learning.

It is the responsibility of the college to ensure quality control and quality assurance on dual enrollment and early admission courses. Colleges should ensure that the course instructor, syllabus, exams, labs, and grading of dual enrollment courses are equivalent to those of corresponding college courses. Close attention should be paid to make certain that these courses not only meet the state's requirements, but that they meet both the admission standards of the two-year institution awarding the credit and those of their transfer institutions.

5.6 Integration of safety.[1] It is highly recommended that chemical safety topics be integrated and assessed throughout the curriculum of all chemistry and chemistry-based courses. Ideally, safety is discussed in broad terms early in the curriculum, with more complex topics introduced as relevant. Isolating safety topics in a single course or lesson can give the impression that safety is no longer relevant after its completion. Additionally, consistent attention to safety throughout the curriculum can help prepare students for their eventual entry into the highly safety-conscious workforce.

Appropriate safety topics for the first two years of chemistry include the following:

- **Principles of safety:** Topics include recognizing and identifying hazards, assessing and evaluating the risks of hazards, minimizing and preventing exposure to hazards, preparing for emergencies, and safety ethics and responsibilities.

- **Preparing for emergencies:** Topics include responding to emergencies, evacuation actions, fire emergencies, classes of fires, fire triangle and fire tetrahedron, types of fire extinguishers, using fire extinguishers, actions for various chemical spills, using emergency eyewashes and emergency showers, elementary first-aid, and emergencies with gas cylinders.
- **Recognizing and identifying hazards:** Topics include language of safety (terms, signs, labels, symbols), safety data sheets (SDSs), current hazard recognition systems including the Globally Harmonized System for Hazard Communication (GHS), information resources about hazards, introductory toxicology, acute and chronic toxicities, corrosives, flammables, fires, explosions, and incompatibles.
- **Assessing and evaluating risks of hazards:** Topics include routes of exposure, risk assessment, evaluating risks of toxic hazards, and occupational exposure limits.
- **Minimizing and preventing exposure to hazards:** Topics include managing risk, eye protection, skin protection, laboratory hoods and ventilation, safety standards for safety equipment, handling chemical wastes, and storing flammables and corrosives.

5.7 Preparatory chemistry courses. Students may need chemistry courses to prepare them for college-level programs of study. Such courses emphasize concepts, critical thinking, and chemical calculations required to be successful in chemistry. They also include a laboratory component equivalent to that in a high school chemistry course.

5.8 General chemistry. Traditionally, general chemistry is a first-year college course sequence designed for science majors and students who aspire to become professional chemists. Completion of general chemistry course work ensures a common background in basic chemical concepts such as stoichiometry, states of matter, atomic structure, molecular structure and bonding, thermochemistry, equilibria, and kinetics. Course work must include a laboratory component.

Common outcomes of general chemistry should include knowledge of basic chemical concepts, strength in quantitative problem solving, preparation for higher-level course work, maturation of students’ knowledge of chemistry, and application of mathematical skills. Students also need to be competent in basic laboratory skills, including laboratory safety, keeping a notebook, use of electronic balances and volumetric glassware, preparation of solutions, chemical measurements using pH electrodes and spectrophotometers, data analysis, and report writing. The diversity of institutions and students requires a wide variety of approaches to optimize the progress of students.

The prerequisites for general chemistry are typically the equivalent of one year of high school chemistry with a laboratory component and three years of high school mathematics, including two years of algebra. For students whose preparation is deficient, successful completion of a developmental or preparatory chemistry course, or its equivalent, as well as the necessary mathematics courses, should be required.

5.9 Organic chemistry. Traditionally, organic chemistry is a second-year course sequence designed for science, chemical engineering, and health-related majors, as well as students who aspire to become chemical professionals. Among the topics typically covered are synthesis, characterization, and physical properties of small organic molecules and macromolecules, and the mechanisms of common organic reactions. In order to ensure articulation of organic chemistry course work, including the laboratory, two-year college programs should collaborate with the institutions to which students transfer to ensure that all required topics are covered appropriately. Typically, the equivalent of two semesters of general chemistry with laboratory is a prerequisite for organic chemistry.

5.10 Chemistry-based technology courses. The specific skills and knowledge required by employers should be identified in collaboration with program partners. If four-year programs are among the program partners, one or more representatives should also participate in the curriculum development.

5.11 Chemistry for allied health and health sciences. Chemistry courses required for students in allied health and health science programs should be developed in consultation with the programs in which the students are enrolled and to which they will transfer. The laboratory component should concretely demonstrate the application of chemistry within the health sciences. Prerequisites should be specified.

5.12 General education chemistry courses. General education chemistry courses should be transferable and include a laboratory component that satisfies the science requirement for graduation. The mathematical requirement is usually elementary algebra. The goal of such courses should be to educate students in the process of science, the molecular perspective of matter, and chemistry's relationship to other sciences, technology, and society. Such courses may be interdisciplinary.

5.13 Other specialty chemistry courses. Focused programs of study, such as those for primary and secondary educators, emergency first responders, and medical technicians, may require specialty chemistry courses. The curricula for such programs should be developed in close consultation with the appropriate professional or academic body for which the course is developed. The content of specialty chemistry courses, being directly relevant to the careers of their students, should, at a minimum, be taught at the level of preparatory chemistry courses (Section 5.7). The laboratory component should concretely demonstrate the application of chemistry within the specialty field.

5.14 Laboratory experience. To learn chemistry and be prepared for future coursework and employment, students must directly manipulate chemicals, study their properties and reactions, and use laboratory equipment and modern laboratory instruments primarily through hands-on, supervised laboratory experiences. Laboratory work in chemistry courses must be designed to give students an understanding that experimental work is the foundation of chemical knowledge. This hands-on experience is necessary for students to understand, appreciate, and apply chemical concepts. It should also develop competence and confidence. Depending on the level and nature of the course, laboratory experiences should include the following activities:

- Anticipating, recognizing, and responding properly to hazards in laboratory procedures and managing chemical wastes
- Using appropriate personal protective equipment, fume hoods, and other appropriate equipment to avoid unwanted exposure to chemicals
- Keeping accurate and complete experimental records
- Performing accurate quantitative measurements

- Interpreting experimental results and drawing reasonable conclusions
- Analyzing data statistically, assessing the reliability of experimental results, and discussing the sources of systematic and random error in experiments
- Communicating effectively through oral and written reports
- Planning and executing experiments through the use of appropriate chemical literature and electronic resources
- Synthesizing and characterizing inorganic and organic compounds
- Maintaining a culture of safety in the laboratory (see Section 7.1)
- Developing additional skills as identified by program partners

Students who will be working in the laboratory in the future, such as chemistry-based technology students, should acquire significant hands-on experience with appropriate instrumentation. The instruments used should be identified in collaboration with program partners (see also Section 4.2).

Some employers prefer to hire graduates with specific certifications. These certifications should be identified with the partners, and the program should be developed with these skills in mind.

Computer simulations that mimic laboratory procedures have the potential to be a useful supplement, but should not be considered equivalent replacements for hands-on experiences critical to chemistry courses at any level.

5.15 Frequency of course offerings. The institution should schedule courses so students can complete a full sequence of general or organic chemistry in a single academic year, or both general and organic sequences in two academic years. Chemistry-based technology courses should be offered with sufficient frequency to allow students to complete program requirements within two years. An annual listing of chemistry courses should be published and widely distributed, permitting students to schedule courses in proper sequence. The schedule of chemistry courses should be coordinated with the schedule of the other required courses within common degree tracks. Ideally, the lecture and laboratory components of a course are taken concurrently.

6. Undergraduate Research, Internships, and Other Experiential Activities

Engaging two-year college students in original research and other scholarly activities has many benefits. It allows students and faculty members to integrate and reinforce chemistry knowledge, develop their scientific and professional skills, enhance their safety and risk assessment skills, create new scientific knowledge, and add new contributions to other knowledge bases.

To prepare students for the workplace, two-year colleges should include some type of internship, research, cooperative learning, or long-term project; for chemistry-based technology programs, which focus on immediate employment, internships and co-ops are especially important. These types of experiences are best provided by the program partners who will ultimately hire the program graduates. If such experiences cannot be arranged, on-campus internships and research projects may be suitable alternatives.

6.1 Research. Student-centered research fosters interactions among students and faculty members and enhances student interest in science. Research activities are also effective in keeping faculty members current in chemistry fields and in a position to enrich contemporaneous course content. Such activities help students, faculty members, and administrators develop an understanding and appreciation of the importance of scientific research in maintaining competitiveness in the global workforce. In addition, experimental work can provide a basis and rationale for acquiring modern instrumentation.

Well-structured research experiences include the following components:

- Defined topic and achievable goals
- Access to and use of appropriate chemical literature and equipment
- Methodologies appropriate for potential publication in a peer-reviewed journal
- Appropriate safety practices
- Supervision by an experienced chemist or instructor
- Written report at the conclusion of the project

If a college is unable to support research on-campus, collaborations with other institutions may yield valuable research opportunities (see Section 10).

6.2 Internships and cooperative learning experiences. Independent work opportunities should parallel experiences one would expect in the workplace. Valuable internships or co-op experiences include the following components:[10]

- Hands-on, independent work that applies the skills and knowledge learned in the classroom
- Use of skills that transfer to other forms of employment, such as critical thinking, verbal and written communication, and workplace ethics
- Specific goals and objectives that apply to the hiring organization and the college (organization's goals and college's goals may be separate, as long as they are defined)
- Supervision by a qualified professional
- Tangible contribution to the work of the group
- Conditions similar to those that interns will experience upon full-time employment
- Routine feedback from experienced supervisor
- Appropriate resources, equipment, and facilities provided by employer
- Appropriate financial compensation, academic credit, or both

As a result of the experience, a written or verbal report, or both, should be submitted to the academic institution.

6.3 Long-term projects. Student-centered research projects can be pursued independently or integrated into the curriculum. Projects can be conducted on campus, in the facilities of partnering institutions, or in other scientific facilities. Developing group or interdisciplinary projects can help broaden the applicability and relevance of chemistry in allied fields.

A suitable project includes the following characteristics:

- It is well-defined, with clear goals and objectives.
- The plan has a reasonable chance of completion in the available time.
- Students develop and apply an understanding of in-depth concepts.

10 National Association of Colleges and Employers. Position Statement: *U.S. Internships—A Definition and Criteria to Assess Opportunities And Determine the Implications for Compensation,* July 2011. http://www.naceweb.org/advocacy/position-statements/united-states-internships.aspx (accessed Sept 11, 2015)

- The research uses a variety of methods and instrumentation.
- The topic is grounded in the chemical literature.

Implementing a student-centered research, internship, or long-term project program requires resources, including faculty time, laboratory space, instrumentation, chemical literature, supplies, and student stipends. The investment is justified by its impact on student learning and the richness it adds to students' and faculty members' scientific experiences.

7. Development of Student Skills for Academic and Professional Success

In order to prepare students to enter the workforce or further their education, two-year college programs should provide experiences that go beyond chemistry knowledge alone to develop other critical skills necessary for effective and productive professionals. Strategies for helping students acquire skill sets needed for successful careers include offering courses dedicated to student skills, integrating student-skill-focused activities into regular curricular offerings, and engaging students in research and internship experiences. Regardless of the approaches used, programs should also assess student skills and adjust the curriculum as needed to maximize their development.

The curriculum should include the skills and knowledge of greatest importance to the program's partners. Hands-on experience should be emphasized and employability skills, such as troubleshooting, searching and interpreting chemical literature, laboratory safety, communication, teamwork, and ethics should be integrated into the curriculum. Students should achieve a mastery of these and other skills required by employers prior to graduation.

7.1 Laboratory safety skills. In order to prepare students for advanced coursework and the workplace, colleges must promote a safety-conscious culture in which students understand the concepts of safe laboratory practices and apply them at all times. Students must be trained in the aspects of modern chemical safety appropriate to their educational levels and scientific needs. A strong safety culture requires that

- A high degree of safety awareness is introduced during the first laboratory course and integrated into each lab experience thereafter

- Classroom and laboratory discussions stress safe practices
- Students are actively engaged in the evaluation and assessment of safety risks associated with laboratory experiences
- Safety understanding and skills are developed and assessed throughout the curriculum

Colleges should provide students with education and training that allows them to:

- Carry out responsible waste management and disposal techniques
- Understand and comply with safety regulations
- Properly use personal protective equipment to minimize exposure to hazards
- Understand the categories of hazards associated with chemicals (health, physical, and environmental)
- Use safety data sheets (SDSs) and other standard printed and online safety reference materials
- Recognize chemical and physical hazards in laboratories, assess the risks from these hazards, know how to minimize the risks, and prepare for emergencies

7.2 Problem-solving and critical thinking skills. Chemistry education should develop students' ability to objectively analyze and evaluate information—identifying information of value, integrating new facts into their existing body of knowledge, and developing appropriate solutions to problems. Students should be able to define problems clearly, develop testable hypotheses, design and execute appropriate experiments, analyze data, and draw appropriate conclusions. Students should use appropriate laboratory skills and instrumentation to solve problems while understanding the fundamental uncertainties in experimental measurements.

7.3 Communication skills. Effective communication is vital in all careers. Since speech and English composition courses alone rarely give students sufficient experience in the oral and written communication of technical information, the chemistry curriculum should include writing and speaking opportunities, and the chemistry faculty should evaluate them critically. Students should be able to:

- Present information in a clear and organized manner
- Create visual representations of complex data sets

- Write well-organized and concise scientific reports in a scientifically appropriate style
- Cite sources properly
- Use appropriate technology, such as poster preparation software, word-processing software, chemical structure drawing programs, and computerized presentations

7.4 Team skills. Solving problems and addressing chemical challenges often involves multidisciplinary teams, and teamwork and leadership skills are critical to success in the workplace. Students should be able to work effectively in a diverse group of peers, as both leaders and team members, to solve problems and interact productively.

As team members, students should learn to work toward a team goal, support teammates, and collaborate on the development of a group plan. Team members should be able to achieve a shared vision, provide productive ideas and feedback, carry out specific assignments, and trust other team members to do the same.

As team leaders, students should be able to provide a clear direction for the team, encourage team contributions, and synthesize individual contributions into a complete product. Team leaders should be able to resolve conflicts, inspire team members, and drive for results.

The faculty should incorporate team experiences in classroom and laboratory components of the chemistry curriculum. Team experiences should be structured so that all students have the opportunity to develop both leadership and team skills.

7.5 Ethics. Ethics should be an intentional part of the instruction in chemistry programs. Students should conduct themselves responsibly and be aware of the role of chemistry in contemporary societal and global issues.

Students should understand their responsibilities, both as students and future chemical professionals, to:[11]

- Serve the public interest and actively protect the health and safety of co-workers, consumers, and the community
- Present results of research or comments on scientific matters with

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11 American Chemical Society. *The Chemical Professional's Code of Conduct;* American Chemical Society: Washington, DC, 2012. http://www.acs.org/content/acs/en/careers/career-services/ethics/the-chemical-professionals-code-of-conduct.html (accessed Sept 11, 2015)

care and accuracy, without unsubstantiated, exaggerated, or premature statements
- Advance chemical science, understand the limitations of their knowledge, and ensure that their scientific contributions, and those of their collaborators, are thorough, accurate, and unbiased in design, implementation, and presentation
- Remain current with developments in their fields and share ideas and information
- Keep accurate and complete laboratory records
- Maintain integrity in all conduct and publications and give due credit to the contributions of others
- Give respect and value to all classmates, educators, colleagues, and others, regardless of race, gender, age, religion, ethnicity, nationality, sexual orientation, gender expression, gender identity, presence of disabilities, educational background, employment history, or other personal attributes
- Understand the health, safety, and environmental impacts of their work
- Recognize the constraints of limited resources
- Develop sustainable products and processes that protect the health, safety, and prosperity of future generations

As role models, faculty and staff members should exemplify ethics in their scholarship and professional conduct.

7.6 Chemical information acquisition and management skills. Essential student skills include the ability to retrieve information efficiently and effectively by searching the chemical literature, to evaluate technical articles critically, and to manage many types of chemical information. Students must be instructed in effective methods for performing searches and assessing their quality using keywords, authors, abstracts, citations, patents, and structures and substructures. Two-year college programs should provide ready access to technical databases with sufficient depth and breadth of the chemical literature for effective searching. Students' ability to read, analyze, interpret, and cite the chemical literature as applied to answering chemical questions should be assessed throughout the curriculum.

Instruction should also be provided in data management and archiving, record keeping (electronic and otherwise), and managing citations and related information. This includes notebooks, data storage, information, and bibliographic management and formatting.

Faculty should consider the development of chemical information skills an evolutionary process that is best integrated throughout the curriculum, beginning with finding specific information and maturing to an ability to critically assess information on broader topics. Additionally, undergraduate research and/or individual or group projects provide excellent opportunities for development and assessment of literature searching and information management skills.

7.7 Career preparation. Students should learn skills associated with identifying and pursuing employment opportunities, such as networking, resume-writing, and interviewing. Students should be cognizant of and prepared for the conditions they will experience upon employment. Activities such as internships, research, job-shadowing, job-based simulations, and mentorships can provide the necessary exposure; programs should identify these or other opportunities that will best serve the long-term career interests of their students.

8. Student Academic Counseling, Career Advising, and Mentoring

Effective academic counseling, career advising, and mentoring foster student success and are an integral part of the institutional environment. Academic counseling provides students with clear pathways for successful and timely completion of their academic goals, through either degree or certificate programs at two-year colleges or transfer to four-year colleges or universities. Career advising provides information about a wide variety of employment opportunities available in chemistry-based careers. Mentoring leads to successful completion of educational and career goals.

Advisers, counselors, and faculty members should help students develop educational goals and guide their professional development via networking opportunities, confidence building, and career planning. A strong collaboration among chemistry faculty, counselors, and advisers at the institution and their contacts at local high schools, receiving institutions, and employers should be fostered and sustained in order to increase students' successful matriculation, transfer, job placement, and achievement of career goals.

In addition to fostering healthy mentoring relationships between students and faculty, programs should create opportunities for students to build relationships with each other in order to foster the development of a community of learners that gives students the support and sense of belonging necessary to succeed academically. Such opportunities may include study groups, ACS student chapters, or student research.

Advisers, counselors, and faculty members should provide information about combining a basic chemistry education with studies in other disciplines. For example, a major in chemistry with supporting work in biology is good preparation for students planning careers in medicine, dentistry, or pharmacy. In addition, many careers in the chemical industry, government, and other areas are open to graduates who have a solid background in chemistry combined with other disciplines, such as computer science, law, economics, environmental science, library science, history, literature, or philosophy.

8.1 Faculty mentors. Given their regular interaction with students, content knowledge, professional background, and community contacts, faculty members can be particularly effective mentors, especially if they maintain communication with employers and four-year institutions. Faculty members should encourage students to consider the career options available within chemistry and support efforts to engage students from underrepresented minorities.

Faculty should be intentional about creating the opportunities for mentoring relationships to occur. While mentorship can take many forms, faculty members engaging students in research are well-situated to provide exceptional mentoring opportunities, as well as to prepare students for successful academic transfers and transitions into the workplace; such research can be an enriching experience for faculty members as well. Faculty members can also guide students toward industrial or government mentors and encourage participation in internships or cooperative education experiences.

Two-year college administration should foster an environment that supports faculty in their mentorship efforts. Faculty members serving in formal mentoring programs should be compensated or given reassigned time.

8.2 Counselors and advisers. Academic counselors should be discipline-specific and provide current information with respect to the most efficient route for completing a certificate or associate's degree, or for transferring to a four-year program. Effective counseling includes discussion of:

- Course prerequisites and skills needed for program completion
- Transfer to higher education or entry into the workforce, as appropriate
- Completion of all terms of required sequential courses (such as the general chemistry sequence and the organic chemistry sequence, if appropriate)
- Mathematics and other science sequences

Career advisers provide guidance for a student's development, networking, confidence building, and career planning; effective advisers are knowledgeable about current and future chemistry-based employment opportunities. Both counselors and advisers should encourage students with strong interests and abilities in chemistry to continue their educations in the chemical sciences.

Two-year colleges should use discipline-specific counselors and advisers to promote familiarity with chemistry and chemistry-related programs and to facilitate articulation with four-year college programs and industry. Both advisers and counselors should communicate with two- and four-year college faculty and community employers to assist students in developing educational plans within the curriculum of the institution that will lead to successful academic transfer or to employment.

Counseling and advising may be the responsibility of college personnel or of faculty as part of their job descriptions. Faculty members serving as advisers or counselors should be compensated or given reassigned time.

9. Program Self-Evaluation and Assessment

Self-evaluation should be an ongoing process leading to continual improvement of a program. A transparent and reflective self-evaluation process that collects, considers, and acts on evidence helps produce prepared students, promote ongoing professional development and scholarly activities of faculty members, and strengthen the infrastructure that supports the educational mission of the program.

9.1 Program goals and objectives. Institutions must ensure that infrastructural support is consistent with the program goals and objectives. The chemistry faculty should implement a variety of assessment techniques and tools, providing the necessary data for making informed decisions at the classroom, course, and program levels. These decisions should lead to the implementation of practices that effectively address the needs of the students.

9.2 Student learning. Assessment of teaching and student learning should be an integral part of the institutional mandate. Programs should have established procedures to regularly assess and evaluate their effectiveness with respect to curriculum and pedagogy.[12] Institutional research offices often have access to aggregate student data on preparedness, advancement through programs, and subsequent performance at four-year institutions. These offices should provide opportunities to survey students during and after enrollment.

9.3 Innovations in instruction. Ongoing assessment and continuing instructional revision improves student learning and reinforces improvements in curriculum and pedagogy. When new courses and pedagogical initiatives are developed, their effectiveness and value should be assessed. Innovation and experimentation in the educational process, coupled with a strong assessment component, should preserve the vitality of chemistry education.

10. Partnerships

To maximize their impact and success, two-year college programs should partner with organizations that have overlapping interests. Two-year college transfer, support, and especially chemistry-based technology programs can be strengthened by collaborating with relevant partners in curriculum development, faculty and institutional support, and the recruitment and placement of students.

12 Many institutions rely on the ACS Division of Chemical Education Examinations Institute (http://chemexams.chem.iastate.edu/) for assessment because it provides a wide variety of tests to assess student learning while providing national norms and statistics. Other assessment instruments may also be used. (accessed Sept 12, 2015)

To be effective, partnerships must benefit all the participants; likewise, all of the partners need to collaborate to actively maintain the partnership. Establishing clear responsibilities and regular communications should help leverage resources and expertise, positioning two-year college programs to respond to the changes occurring in education and the workforce.

Partnerships are especially important for the maintenance and growth of strong chemistry-based technology programs. These institutional relationships provide knowledge of the skills employers require of graduates, resources to develop the necessary program infrastructure, career opportunities for graduates, and, frequently, students for the program. The program's partners should also be consulted in determining the appropriate faculty, support staff, facilities, and equipment for the program.

10.1 Advisory boards. An advisory board whose members have a vested interest in the program's success is a critical component of a strong chemistry-based technology program; advisory boards can also benefit transfer and support programs. The members should represent the employers, institutions, organizations, and campus units, as appropriate, that are partnering with the program. The advisory board is responsible for:

- Developing and maintaining the program and its curriculum
- Ensuring that the program and its curriculum keep pace with the changing needs of the partners, potential employers, and/or transfer programs
- Maintaining a curriculum flexible enough to support a variety of employer or transfer program needs
- Ensuring students have transferable skills that can support a variety of career trajectories
- Providing employer-based mentorships, as appropriate

10.2 Campus units. The quality and success of chemistry programs is dependent upon interactions among campus units. Strong coordination and ongoing communication should occur among the chemistry faculty, staff providing support services, and counselors and advisers who help students with course placement, sequencing, transfer options, and career opportunities. By establishing collaborative activities, programs will leverage and increase the effectiveness of their efforts. Such activities may be supported by external funds.

Interactions among departments and disciplines should also be encouraged. The institution should provide opportunities for interdisciplinary discussions and collaborations among faculties, ensuring that students receive a well-rounded collegial perspective on chemistry.

10.3 Higher education institutions. Partnerships among two-year and other post-secondary programs take many forms and have many benefits. Collaborative faculty projects and group meetings, articulation conferences and workshops for faculty, and undergraduate research are just a few examples. In addition to enriching students and faculty members, such partnerships foster student transfer, increase student retention, and enhance and expand program offerings.

Successful student transfer requires candid and ongoing conversations between faculties at two-year colleges and receiving institutions. This is particularly important when curricular changes are being made and when students enroll in and transfer to a number of different receiving institutions. The conversations should serve to align curricular content and allow for exchange of ideas in delivering effective instruction and developing new approaches to strengthening student success at both transfer and receiving institutions.

Two-year college chemistry programs choosing to match the first two years of an ACS-approved program in chemistry must be familiar with the current guidelines for bachelor’s degree programs and the way in which the ACS-approved program has implemented them. Students wishing to obtain a bachelor’s degree from an ACS-approved program, particularly a certified degree, should also consult with a representative from that program and refer to *Undergraduate Professional Education in Chemistry: ACS Guidelines and Evaluation Procedures for Bachelor’s Degree Programs* at www.acs.org/CPT (accessed Sept 15, 2015).

Each institution involved should have a mechanism for coordinating and communicating to students, faculty, counselors, and advisers the terms of articulation agreements. Agreements that specifically describe the courses and learning outcomes necessary for efficient transfer are the keys to student-centered advising.

Partnerships with other institutions of higher education can leverage resources, enhancing and expanding the offerings of two-year programs. If two or more institutions in the same geographical area are unable to offer a complete two-year chemistry program individually, the institutions should consider combining resources and facilities to provide a full two-year chemistry program. Institutions with programs in place can also benefit from cooperative agreements, gaining access to libraries, laboratory facilities, and sophisticated instrumentation on other campuses. Second-year and specialized occupational courses, in particular, can be improved by such partnerships. These agreements can also make participation in research by faculty members and independent study students a reality.

10.4 K–12 Institutions. Partnerships with high schools can be a valuable mechanism for identifying and recruiting talented students early in the college-planning process. These relationships also provide an opportunity to align curricula, manage expectations, and enrich both high school and college education. Early admission, dual enrollment, and even advanced standing for certain high school courses also function in valuable ways to recruit students and increase the number of enrollments of first-generation and other students who are not otherwise likely to matriculate directly into college. Any course offered at a secondary school that results in a grade appearing on a college transcript must be taught by an individual qualified to teach the comparable course at the college. Such an arrangement should involve close oversight, review, and assessment by the college chemistry faculty to ensure similar levels of academic rigor and consistent learning outcomes (see also Section 5.5).

Partnerships with K–12 institutions can be very beneficial for programs preparing students for careers in teaching, providing professional development for in-service teachers, and preparing chemists to transition to careers in K–12 education.

10.5 Employers. Because most students will seek employment at some point, partnering with industrial and government employers is a key step to ensuring that students have the skills desired in the workplace. As partners, employers can identify and continuously update skills they require, provide employment trends and projections, and ensure that curricula, course content, and programs meet their needs. Since the needs of employers can vary greatly by region and industry, partnering with employers is critical for chemistry-based technology programs.

Cooperative agreements with industrial and government laboratories can provide access to libraries, laboratory facilities, and sophisticated instrumentation, enhancing the curricular offerings and research opportunities of two-year programs. Employers can provide professional development to both faculty and students in the form of research positions, internships, and other experiential opportunities.

Particularly in chemistry-based technology programs, employers can provide valuable mentorships, guest speakers, laboratory tours, and other experiences that support students' career development. Some employers may also be able to provide funding, equipment, or even part-time instructors for specialty courses. Employers can assist with student recruitment, through both participation in career fairs and enrollment of current employees interested in expanding their skills.

By partnering with two-year college programs, employers can gain access to a more qualified workforce pipeline, assistance with the professional development of incumbent employees, and potential tax benefits. Employers and programs should communicate their respective needs frequently, honestly, and with an eye toward creative solutions to potential roadblocks.

10.6 Other nonacademic institutions. Other nonacademic institutions can also assist with career development. Laboratories, museums, and workforce development agencies are among those institutions that can host field trips and serve as sources of speakers and potential role models and mentors for students. Interactions among faculty and employees of these institutions can provide valuable insights and information to be shared with students during chemistry courses and conversations about careers.

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