ACS Guidelines for Chemistry in Two-Year College Programs

The following is an excerpt from the *ACS Guidelines for Chemistry in Two-Year College Programs*. American Chemical Society: Washington, DC. 2015.

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

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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.