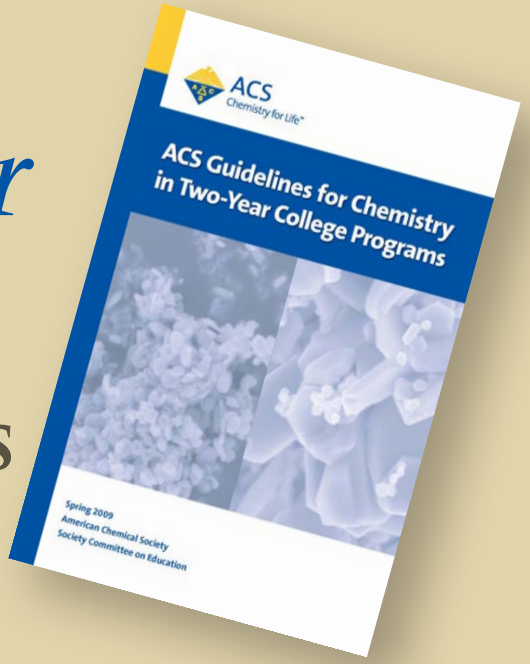
ACS Chemistry for Life®

American Chemical Society

Use of the *ACS Guidelines for Chemistry in Two-Year College Programs:* A Collection of Case Studies



Introduction

Since 1970, ACS has maintained guidelines to promote high-quality chemistry education for students in two-year college programs. The most recent revision of the *ACS Guidelines for Chemistry in Two-Year College Programs* was released in 2009 after a four-year process of gathering community input.

The ACS Guidelines provide a comprehensive model for excellence in chemistry education that can be applied across a broad spectrum of two-year college transfer, applied, and support programs. Recognizing this diversity of missions and goals, ACS encourages individual programs to identify and implement those recommendations that will enhance the quality of their particular institutions' chemistry education.

To facilitate the implementation of the Guidelines, ACS solicited examples of the use of various recommendations from the two-year college chemistry community in late 2010. The responses formed the basis for the 12 case studies in this document. The faculty featured here have used the Guidelines to inform faculty policies, optimize class sizes, guide laboratory renovations, develop curricula, strengthen partnerships, and evaluate programs. We invite readers to use these case studies as models for implementing the Guidelines at their own institutions and to share their experiences with us.

Copies of the *ACS Guidelines for Chemistry in Two-Year College Programs*, supplements, and other materials can be found on the ACS web site at **www.acs.org/2YGuidelines**. Questions, comments, suggestions, and requests for hard copies should be directed to:

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Cerro Coso Community College

Ridgecrest, CA

- IPEDS enrollment, Fall 2010: 6,642 students
- Type of community: Rural
- Number of campuses: 5
- Number of chemistry students, Fall 2011: 80
- Number of full-time chemistry faculty: 1
- Number of adjunct chemistry instructors: 1
- Structure: Chemistry is part of the Sciences and Engineering Department
- Focus of chemistry program: Transfer
- Sections of Guidelines used: 4.1, 5.1–5.11, 7.1–7.6, 10.4

John Stenger-Smith, a chemistry professor at Cerro Coso Community College, has used the *American Chemical Society (ACS) Guidelines for Chemistry in Two-Year College Programs* to

- Support articulation by providing a rigorous curriculum
- Maintain hands-on laboratory experiences in the curriculum
- Inform the design of a $4 million renovation of the college's science laboratories
- Obtain permission for students to use nuclear magnetic resonance spectroscopy at a naval base

The size of Cerro Coso Community College's service area creates unusual challenges for faculty and students. At 18,000 square miles, the college has the largest geographical service area of any community college in California. The area, which borders the Mojave Desert, is bigger than several New England states and has just 85,000 residents. How to serve students appropriately online and on campus is a key issue for the college, particularly its one full-time chemistry instructor.

Influencing Curriculum

Because almost all of the 80 students whom Stenger-Smith teaches each year transfer to baccalaureate institutions or research universities, his priority is making sure their chemistry credits will be accepted wherever and whenever they matriculate. "I want to make sure...that they transfer," he said, referring to students and their credits. Students generally transfer to public California universities, but each year a few students move on to four-year institutions in other parts of the country. With students transferring to so many different colleges, Stenger-Smith finds it beneficial to use both the *ACS Guidelines for Chemistry in Two-Year College Programs* and the *ACS Guidelines and Evaluation Procedures for Bachelor's Degree Programs* to structure his lectures and labs.

By using ACS's standardized exam as the final exam for his rigorous organic chemistry sequence, Stenger-Smith has been able to provide evidence, even several years later, that students have mastered the same concepts, theories, and practices as students at four-year institutions. He has persuaded both the University of Chicago and the University of California, Berkley to grant credit to former students by sharing information about his curriculum and documenting students' scores on the standardized exam.

Former student Michael Garrison is one beneficiary of the rigorous curriculum. Garrison's perfect score on the ACS exam in May 2006 was recognized by the ACS Mojave Desert Section. John McMurry, the author of the organic chemistry textbook used at Cerro Coso, also sent Garrison a letter with his congratulations. Garrison transferred to the University of California, Irvine, where he earned a bachelor's degree in chemistry with honors. He has received a fellowship to continue his graduate studies in chemistry there.

In response to the recommendation in the 2009 edition of the Guidelines that science majors "be able to use the peer-reviewed scientific literature

and evaluate technical articles critically," Stenger-Smith has added critical evaluations of media reports about scientific breakthroughs to class assignments. In 2010 he had students examine the "arsenic-loving bacteria" studies, as well as critiques of those studies.

Addressing the Use of Computer Simulations

Around 2005, an administrator (who is no longer at the college) suggested that Stenger-Smith teach chemistry online with virtual labs. Stenger-Smith used the Guidelines to inform the administrator of the value of hands-on experiences.

Section 5.10 of the Guidelines states, "To learn chemistry, students must directly manipulate chemicals, share their properties and reactions, and use laboratory equipment and modern laboratory instruments ... This hands-on experience is necessary for students to understand, appreciate, and apply chemical concepts." Consequently, "Computer simulations that mimic laboratory procedures have the potential to be useful supplements, but should not be considered equivalent replacements for hands-on experiences critical to chemistry courses at any level." After several conversations, the administrator understood the value of hands-on experiences, and the pressure to use computer simulations faded away. "Our current administrative environment is very supportive of hands-on labs for chemistry," Stenger-Smith explained.

To deal with the issue of online labs and hybrid classes in a more comprehensive way, however, Stenger-Smith convinced the Sciences and Engineering Department to adopt a procedure using the ACS Guidelines and other professional societies' standards to guide departmental decisions about class sizes and curriculum. The procedure states: "New iTV (the college's interactive television system) or online classes will not be offered in this department unless the technology exists to offer the class as closely as possible to the on-ground course and the Science Class can be taught with the appropriate level of rigor via online or iTV. Online and iTV classes in particular will also be evaluated with respect to appropriateness and professional society guidelines. In the Science Department all lab classes will follow the safety procedures dictated by the discipline's professional society."

Informing Laboratory Design

Improving the safety of Cerro Coso's chemistry laboratories was one of several reasons the college sought a bond issue for the $4 million renovation of its science laboratories. The new facilities opened in 2010–2011.

Stenger-Smith said he and other faculty members in the Sciences and Engineering Department who were part of the facility planning process persuaded the architect to abandon his pod design for the chemistry laboratory by showing him the recommendation in the Guidelines that facilities include laboratory tables and benches. The architect also raised the possibility of virtual laboratories. "It took about four very strongly worded statements on my part to stop his pushing virtual labs," Stenger-Smith recalled. The new laboratory has a chemical storage cabinet, updated fume hoods, eye washes, and other safety equipment.

Accessing Equipment at a U.S. Navy Base

ACS policies are behind the long partnership the chemistry faculty at Cerro Coso Community College has had with the Naval Air Warfare Center Weapons Division in China Lake. The chemists who work at the base include ACS members who support the Society's recommendation that nonacademic institutions share their resources with educators and students, according to Stenger-Smith. His predecessor at the college had developed the agreement that allows the college's chemistry professor and students to use the nuclear magnetic resonance spectrometer at the naval base.

"Being able to do real mass spectroscopy on research-grade equipment is a huge advantage for students," Stenger-Smith said.

The content of this case study was provided by John Stenger-Smith. Stenger-Smith joined the Cerro Coso faculty in 2000, after working as a chemical engineer for the U.S. Department of the Navy. He earned his bachelor's degree in chemical engineering from the University of Delaware and his Ph.D. in chemical engineering from the University of Massachusetts Amherst. Stenger-Smith has been granted 22 patents. He has written or co-authored more than 100 articles and edited three books on nonlinear optical polymers, electroactive polymers for charge storage devices, and electroactive polymers for corrosion inhibition.

COLLEGE OF THE CANYONS

College of the Canyons

Santa Clarita, CA

- IPEDS enrollment, Fall 2010: 23,332
- Type of community: Suburban
- Number of campuses: 2
  (chemistry courses are offered only at the main campus)
- Number of chemistry students: 1,100
- Number of full-time chemistry faculty: 5
- Number of adjunct chemistry instructors: 8–10, depending on the semester
- Structure: Chemistry Department is part of the Division of Math, Science, and Engineering
- Focus of chemistry program: Transfer
- Sections of the Guidelines used: 3.2, 4.1, 5.1

Kathy M. Flynn, professor of chemistry at the College of the Canyons, reports that administrators and faculty members involved in the college's course approval process readily accept the *American Chemical Society (ACS) Guidelines for Chemistry in Two-Year College Programs* as an authority. The College of the Canyons has used the Guidelines to

- Cap enrollment in chemistry classes at 24 students
- Include on-campus labs for online chemistry courses
- Influence plans for new laboratories

When Flynn began teaching at the College of the Canyons in 1993 as an adjunct instructor, it was not uncommon for 30 students to be crammed elbow-to-elbow in the college's one chemistry laboratory. Everyone shared glassware and bench space. "It was not the best teaching environment," she said. Within a few years, the college renovated classrooms to make two additional laboratories. Then in 2008, with state funds and a bond for a second science building, the college built a new organic chemistry laboratory with a stockroom and storage facility near the other chemistry laboratories.

In 2011, with 4 labs and 18 sections spanning 7 different courses, demand for chemistry instruction exceeded the college's capacity to provide it. This situation has occurred frequently since 2006, when enrollments began to grow quickly. Waiting lists for chemistry courses are now common.

Balancing Enrollment Growth and Supervision of Students in Laboratories

By adhering to the Guidelines, the college's chemistry faculty members have prevented a return to overcrowding in laboratories. Flynn explains that faculty "have been vocal about keeping to the class size recommendations set forth by ACS [and] the administration has been open to this recommendation."

As the Chemistry Department created new courses over the years, faculty members would cite the Guidelines in their formal requests to limit enrollment to 24 students. Older courses were grandfathered in and generally had more than 24 students until 2008, when Flynn and her colleagues began updating the outlines for all existing courses. Their revised outlines included the 24-student cap.

"It's been a little bit of a negotiation," Flynn said of the queries she has fielded as one of the senior, full-time members of the Chemistry Department. Often faculty members and administrators involved in the college's seven-level course approval process, which takes about two years to complete, have asked about the relatively small class size.

"There's always a question about the cap," Flynn said, explaining that the question is asked more in a spirit of discovery than of antagonism. "It's not that they're saying you can't do it. They just want to know why."

Before the Curriculum Committee considers a new or revised course, the following people must approve it: the department chairman, the division dean, computer support personnel, facilities personnel, the articulation officer, the matriculation officer, and the chief instruction officer. At the Curriculum

Committee meeting, the author of the chemistry course usually gets a "Justification, Please" request about the cap. With this level of scrutiny, an instructor's pedagogical preferences are not sufficient; documentation of the need for a smaller class size is required.

Flynn finds the most effective answer to be pointing colleagues to the recommendation in the Guidelines that "laboratory capacities should not exceed 25 students" and "no faculty member should be responsible for more than 25 students in a laboratory at one time."

There has been some discussion about separating the lecture and lab sections in order for a single large lecture to serve more students, who would then separate into groups of 24 for labs. So far this has not happened because the chemistry faculty consider the small class size a strength in dealing with the varied academic skill levels of the college's diverse student population. Without an ACS position on the effectiveness of instruction in larger lectures, faculty members have relied on their personal teaching experience in deciding this point.

Blending Online Delivery with In-Person Labs

The College of the Canyons uses a hybrid format for its online chemistry courses: Lecture materials are delivered online, and students come to campus for chemistry labs. Although this blended delivery does not satisfy everyone, Flynn said that so far it is the best option for providing students with flexible learning opportunities that meet the recommendation in the Guidelines that students have hands-on experiences manipulating chemicals, studying their properties and reactions, and using modern laboratory equipment and instruments.

Rebecca A. Eikey, chair of the Chemistry Department, explained that by requiring students who take chemistry online to come to campus for labs, the college ensures that they engage in three to six hours (depending on the course) of lab experiments and instruction each week. Flynn describes online delivery as a work-in-progress because faculty are trying to keep up with technology advances and are also attempting to determine what works best for students. One of the challenges the faculty is still considering is the question of how to provide chemistry tutoring online.

Influencing the Design of New Laboratories

The Guidelines have also been a factor in the college's design of new laboratories. According to Eikey, discussions of the new chemistry laboratories that the college would like to build at its Canyon Country campus have included mention of the Guidelines. During the early planning in fall 2011, the new laboratories were slated to have 12 stations and accommodate up to 24 students.

"It is great to have these Guidelines as a reference point," Eikey wrote in an e-mail.

The content of this case study was provided by Kathy M. Flynn. She earned her bachelor's and master's degrees from San Diego State University and her Ph.D. in inorganic chemistry from the University of California, Davis. She was an adjunct instructor at the College of the Canyons and Los Angeles Pierce College before becoming a full-time member of the Chemistry Department faculty at the College of the Canyons in 1999. She also previously served as director of the college's nanotechnology program. Prior to embarking on a college teaching career, Flynn worked in industry as a chemist.

Lake Michigan College

Benton Harbor, MI

- IPEDS enrollment, Fall 2010: 4,739 students
- Type of community: Small city
- Number of campuses: 3 campuses and 1 center
- Number of chemistry students, Fall 2011: 180
- Number of full-time chemistry faculty: 3; 2 teach only chemistry; 1 teaches chemistry and biology.
- Number of adjunct chemistry instructors: 8
- Structure: Chemistry is part of the Science Department, along with biology, physics, and geology.
- Focus of chemistry program: Transfer preparation and support of the college's allied health programs and its Energy Production program.
- Sections of the Guidelines used: 2.2, 3.1–3.4, 4.1, 4.2, 4.5

Bal Barot used the *American Chemical Society (ACS) Guidelines for Chemistry in Two-Year College Programs* to

- Address safety issues though policy, staff, and infrastructure improvements
- Improve curriculum
- Redesign teaching facilities
- Inform faculty policies, such as those addressing contact hours, professional development, and communication of effective practices

Several less-than-optimal practices had evolved over the years at Lake Michigan College (LMC) that were symptomatic of outdated curricula, instrumentation, and labs. For instance, chemistry faculty members used their personal autos to transport the chemicals they used for laboratory sections at two branch campuses. Funds for professional development were limited. Poor student performance and low persistence were discouraging the college's and community's desire to expand LMC's transfer and technical programs in advanced technology and scientific fields.

Justifying Curricular and Infrastructure Changes

In October 2007, the college was awarded a 5-year, $1.9 million U.S. Department of Education Strengthening Institutions Title III grant to improve its science programs. Paige E. Eagan, a chemistry professor who wrote the Title III grant and later coordinated its implementation, cited various sections of the ACS Guidelines to explain why the college needed to revise its curriculum, remodel its lab facilities, and purchase new equipment.

Part of the grant application addressed insufficient safety resources and support staff in science laboratories. It stated: "A 2005 audit conducted by the Laboratory Safety Institute graded LMC science labs a 'D+' for safety. Safety components are outdated and in need of renovation. Audit recommendations include: establish a system-wide method for chemical storage; repair existing and install additional fume hoods; improve chemical storage procedures and facilities; and hire a chemical hygiene officer. According to the *American Chemical Society's Guidelines for Chemistry in Two-Year Colleges,* at least one full-time laboratory technician for every 4 full-time or full-time equivalent chemistry faculty teaching a 15-hour contact load in chemistry is needed. Applying these guidelines to LMC science faculty, two part-time lab assistants support 11 full-time faculty and 14 adjunct."

Revising the Curriculum

One of the most unusual aspects of the college's improvement efforts was the release of all full-time faculty from teaching, so they could concentrate on revising their courses. In Fall 2008, the biology faculty revised their courses while adjunct instructors taught their classes. In Fall 2009, the chemistry, physics, and geology faculty members were released from their teaching duties to concentrate on revising their courses. Eight chemistry courses and a total of 22 science courses were revised. The college considered four options for accomplishing the curriculum revisions before determining that the mass release was the least expensive and fastest way to

implement the changes.

Influenced by the Guidelines' recommendation to teach chemistry as an experimental science "using appropriate and substantial laboratory work that provides opportunities for open-ended investigations," the chemistry faculty adopted a more interactive pedagogy. It blends lectures with demonstrations and discussions with experiments. In 2010, the college also added student resource rooms where molecular kits and computer equipment are available for students to study individually or in groups.

Addressing Infrastructure Issues

About the time the current edition of the Guidelines was released in 2009, chemistry faculty members and college administrators attended a chemical safety program presented by James A. Kaufman, chief executive officer of The Lab Safety Institute. Kaufman also analyzed the condition of the college's labs. The improvements he recommended were based on the ACS Guidelines as well as the safety procedures that his nonprofit consulting organization had developed for instructors at secondary schools and colleges. Armed with this more-detailed information, Barot and his colleagues engaged college administrators in conversations about ways to improve the college's procedures for handling the chemicals used for teaching.

With the Title III funds, the college hired a full-time lab manager who oversees operation of both the chemistry and biology labs at the main campus and two branch campuses. The lab manager's duties include visiting every chemistry course section early each semester to talk with students about chemical safety and keeping the chemical hygiene plan up to date. The manager also makes sure that chemicals are transported to and stored at all three campuses in accordance with the ACS Guidelines and other relevant regulations. A part-time lab assistant now helps faculty and students in the chemistry laboratories. The college has a plan to sustain both positions from the college operating budget when the federal grant ends.

Redesigning Laboratories

Barot, Eagan, and their colleagues used the Guidelines to influence plans for the renovation of the chemistry labs on the main campus. The faculty wanted to reconfigure the space to combine classrooms and laboratories in order to implement the new curriculum and pedagogy. However, the architect's initial plan for these combined spaces called for large lecture halls and labs that would hold many more people than the 25-student limit the Guidelines recommend.

At subsequent meetings with the architect, contractor, and administrators, the chemistry faculty explained that the larger lecture rooms were fine, but that the laboratories should be built to accommodate only 24 students at a time for safety reasons. With the Guidelines to support the faculty's points, the issues were quickly resolved. "There is absolutely no way to convince them to cap enrollment at 24 students without the Guidelines," Eagan said. The renovated chemistry classrooms have new instruments and accommodate both labs and lectures, with approximately 50 square feet of lab table and bench space per student.

Informing Faculty Policies and Practices

In addition to influencing the recent hiring of lab personnel, the Guidelines have historically been a factor in faculty contract negotiations at LMC. A chemistry professor, William Rudman, led the faculty union for many years, Barot explained. Rudman's leadership ensured that the recommendation in the Guidelines that contact hours "not exceed 15 total hours per week" became part of the of the faculty's negotiated agreement.

About five years ago, the college began allocating $1,000 per year for each full-time faculty member to use for professional development. In 2011, the professional development allotment increased to $1,700 per year. Additionally, the college holds an open competition for summer professional development funds. A faculty committee reviews their colleagues' proposals and makes awards in increments of several thousand dollars from a pool of professional development funds. When a new dean was hired, Barot talked with his new boss about the Guidelines' recommendations for professional development. He wanted to be sure that the dean understood the rationale for keeping professional development in the budget despite financial constraints.

Barot has been an ACS member since the 1980s. Because not all of his full- and part-time colleagues are ACS members, Barot makes sure that copies of the Guidelines are available in the faculty meeting room for his colleagues' reference. He also tries to talk with the adjunct instructors about the Guidelines to build a community of support for the effective practices that ACS advocates.

The content of this case study was provided by Bal Barot. In 2011, Barot received a Fulbright U.S. Scholar award and was named College Science Teacher of the Year by the Michigan Science Teachers Association. He holds a Ph.D. in chemistry from Oklahoma State University. As a Fulbright Scholar, Barot taught chemistry for six months at Cochin University of Science and Technology in southern India. Before joining Lake Michigan College's faculty in 1993, he taught at Otero Junior College, La Junta, CO.

Minneapolis Community & Technical College

Minneapolis, MN

- IPEDS enrollment, Fall 2010: 10,545
- Type of community: Urban
- Number of campuses: 1
- Number of chemistry students: 2,000; plus 150 biotechnology students
- Number of full-time chemistry faculty: 4; plus 2 biotechnology instructors
- Number of adjunct chemistry instructors: 5–7
- Structure: Chemistry and Biotechnology programs are part of the Science Division
- Focus of chemistry and biotechnology programs: Transfer, A.S. degrees, and employment
- Sections of the Guidelines used: 4.1, 5.10

Rekha Ganaganur, a chemistry and biotechnology faculty member of the Minneapolis Community and Technical College (MCTC), along with chemistry department faculty members Kirk Boraas, Lijin Shu and Wendy Naughton, used the *American Chemical Society (ACS) Guidelines for Chemistry in Two-Year College Programs* to transform MCTC's chemistry and biotechnology programs. Beginning in 2004, Ganaganur has served as the faculty lead for developing the associate of science transfer degrees in chemistry and biotechnology. The chemistry and biotechnology faculty members helped plan the new science facility, where chemistry classes are limited to 18 students. The faculty used the ACS Guidelines to:

- Advocate for a new associate of science degree in chemistry and the competencies introduced in the biotechnology curriculum
- Expand course offerings
- Influence the design of and equipment selection for a new Science and Allied Health Building

When the MCTC biotechnology program was being developed in Spring 2005, Ganaganur and her colleagues wanted to move the chemistry department beyond offering a few transfer courses. They envisioned adding new courses and implementing a chemistry associate of science (A.S.) degree program. These curricular changes were not possible with the two chemistry labs and limited equipment they had at the time.

Updating Facilities and Curricula

The process of reviewing and updating began when MCTC administrators wanted to boost momentum in the sciences. They also shared the science faculty's interest in new curricula and facilities. In 2005, the administration and faculty began planning a new associate of science degree in biology and a new program in biotechnology.

"From my experiences as a researcher and industry scientist in both chemistry and the biosciences, it was very clear from the beginning that it was important to strengthen the chemistry ... at the same time [we developed the biotechnology program]," Ganaganur explained. Results from a survey of biosciences industries and suggestions from the college's industry advisory council both mentioned chemistry skills that should be part of the new biotech program.

In this context, Ganaganur proposed a new associate of science chemistry degree to then-Dean Janis Hollenbeck. The dean agreed that having both chemistry and biotech would allow students to pursue both majors and meet the transfer requirements for multiple disciplines.

Administrators were "very receptive" to using the ACS Guidelines to plan the new programs, agreeing that the Guidelines would help with accreditation and add value to students' credentials. Then the formal Minnesota State Colleges and Universities (MnSCU) process began. In addition to a series of presentations at multiple academic administration levels, it required a transfer agreement with at least one MnSCU institution. However, the courses,

skills, and competencies that industry employers seek often vary from the requirements of traditional four-year programs. Careful planning based on the ACS Guidelines and the completion of the new science facility allowed MCTC to introduce a unique set of courses, which meet both transfer program and industry needs. The college has established articulation agreements with several institutions and is completing negotiations with the University of Minnesota.

Influencing the New Building's Infrastructure

While college leaders obtained a $20 million construction bond from the state government, the chemistry, biotechnology, and other science faculty worked on a planning committee to shape the architecture and infrastructure of the new science building. Ganaganur says the committee used the Guidelines almost as a checklist for the fume hoods, biosafety cabinets, safety features, bench space, and instrumentation for the new laboratories. Advice from MCTC's industry advisory board, Department of Labor publications, and BIO-Link (the National Science Foundation-funded Advanced Biotechnology Education Center) also influenced their thinking, along with reviews of other relevant entities' recommendations.

Ganaganur compared planning meetings to negotiating sessions, most notably regarding the faculty's requests for the square footage of the labs, the number of fume hoods, and instrumentation space. Although these requests complied with the ACS Guidelines, they somewhat exceeded Minnesota's standard for two-year colleges. MCTC faculty also had to explain at length their requests for a walk-in cold room, dark room, and cell-culture room for the biotechnology program.

The chemistry and biotechnology faculty successfully advocated for lowering the faculty-to-student ratio to 1:18 by explaining that it was in the students' best interests. While this ratio is lower than what is recommended in the Guidelines, Ganaganur exaplained, "We have a lot of urban and immigrant students who do not necessarily come to college ready for these courses...They need a lot [of] additional support and supervising in the labs," Ganaganur said. She noted that faculty advocated for fewer students in the lab because MCTC does not employ teaching or lab assistants. The faculty has to supervise all the students directly while attending to safety and dealing with any issues concerning students' limited fluency in English.

In the new Science and Allied Health Building, the instructor's station and instrumentation occupy a central area in each lab to ensure a commanding, unobstructed view of the entire room. All the students' benches are in full sight of the instructor. The fume hoods are located on the periphery. The Chemistry Department's section of the building includes three dedicated labs, a preparation area, and chemical storage area. Because they are essential to the biotech program, the organic chemistry and microbiology labs are strategically located next to the biotechnology facilities. They, in turn, include a dedicated biotech lab, a cold room, a dark room, a cell-culture room, a preparation room for the labs, and a central instrumentation room.

The college provided the initial funding to build and equip the new labs from the state bond and its regular operating budget. Then the high quality of the programs quickly gained the support of MnSCU and local industry leaders, who helped Ganaganur obtain several grants and corporate support. In recent years, the programs have successfully leveraged this recognition to build partnerships with more employers, professional associations, the region's universities, and key organizations outside Minnesota.

Within MCTC, chemistry and biotechnology faculty members have used the cross-disciplinary aspects of their courses to collaborate with other departments. Faculty applied for and received excellence award funds to infuse interdisciplinary content and activities across multiple departments. Ganaganur has also held workshops for high school teachers and faculty members from two-year and four-year colleges on several topics. She has also submitted several grants with four-year universities.

Since the introduction of the new courses and the A.S. degree programs in biotechnology and chemistry, and the opening of the new science facility in Fall 2008, enrollments have increased tremendously. Additionally, many faculty from other colleges have called, e-mailed, or visited MCTC to learn about its programs and the lab facilties' design. For instance, approximately 70 people from the National Association of Biology Teachers' conference toured the campus labs during their meeting in Minneapolis.

Involving Students in Research

"In terms of curriculum, we again followed the ACS Guidelines, because how we developed and built the labs also had a direct effect on what kind of curriculum we can or cannot have," Ganaganur explained.

The MCTC chemistry and biotechnology faculty made a point of aiming for the recommendations for ACS-approved baccalaureate and chemistry-based technology programs. They wanted the rigor of their courses to match the expectations both of the four-year programs into which a majority of MCTC students transfer and of employers who hire technicians. Their curricula also incorporate ACS recommendations for laboratory safety skills, as well

as Occupational Safety and Health Administration regulations and the Food and Drug Administration's regulations. By meeting these multiple regulatory and quality control expectations, the faculty intended to prepare students for employment—either immediately or eventually—in a wide range of settings. The chemistry and biotechnology programs also combine Program Learning Outcomes and the assessments referred to in the ACS Guidelines with industry guidelines.

The ACS Guidelines helped MCTC launch respected programs in chemistry and biotechnology, which are housed in carefully thought-out laboratory facilities. The labs, the program's academic rigor, and the addition of an undergraduate research method course make it possible for MCTC faculty and students to collaborate on research projects and continuously seek other research opportunities. Examples include;

- MCTC students now participate in NSF-summer Research Experiences for Undergraduates (REU) programs at multiple universities. Ganaganur has re-established NSF-REU partnerships with University of Wisconsin, Eau Claire, and is in the process of establishing similar partnerships with other universities.
- A new NSF-supported partnership with Cold Spring Harbor Laboratories, a bioscience research institute in Cold Spring Harbor, NY, along with BIO-Link, will enable Ganaganur to introduce other research projects at MCTC and to host and co-teach workshops for faculty from other institutions.
- Newly hired faculty and Ganaganur have attended a Council on Undergraduate Research workshop and have teamed up to develop the MCTC–Undergraduate Research Initiative.

Ganaganur has several reasons for involving students in research. She wants to provide early research opportunities to students who are interested in this career path. She also wants to give students who plan to enter the workforce after completing two-year degrees the advantage of real laboratory work experiences so they can list this experience on their resumes when they apply for employment in commercial and academic labs.

However, the key reason she seeks to involve associate-degree students in research is that it helps them become more competent and more capable when they enter the workforce, even if it is not until after they complete baccalaureate degrees. Ganaganur has found that having students do research is the best way to help them overcome their fears of working independently in the lab.

The content of this case study was provided by Rekha Ganaganur. She has been a member of the science division at MCTC since 2004 and is the lead faculty member of the biotechnology program. She earned bachelor's and master's degrees from the University of Mysore and a Ph.D. from Bangalore University, India. She had several years of postdoctoral research, industry, and teaching experience before joining MCTC. She is one of 12 US faculty leaders who are co-teaching Bio-Link's Genomics in Bioscience program. It provides genetics education workshops developed by the Cold Spring Harbor Laboratories: Dolan DNA Learning Center for secondary and college educators.

SCC
ST. CHARLES COMMUNITY COLLEGE

St. Charles Community College

Cottleville, MO

- IPEDS enrollment, Fall 2010: 8,202
- Type of community: Suburban, but draws students from a rural area
- Number of campuses: 1
- Number of chemistry students, Fall 2011: 500
- Number of full-time chemistry faculty: 3
- Number of adjunct chemistry instructors: 12
- Structure: Chemistry is part of the Science Department, which is part of the Math, Science, Health, and Wellness Division
- Focus of chemistry program: Transfer
- Sections of the Guidelines used: 4.1, 4.2, 5.4, 5.9

John Bookstaver, a professor of chemistry at St. Charles Community College (SCCC), used the *American Chemical Society (ACS) Guidelines for Chemistry in Two-Year College Programs* to

- Inform plans to renovate laboratory facilities
- Select new equipment
- Update software

Although the college's chemistry lab was in a building that opened in 1994, it was the first building constructed on campus when the college was new and small. During the past 20 years, the pace of population growth in St. Charles County was among the fastest in the United States. As enrollment in SCCC grew, the college's one chemistry lab was not sufficient. Of even greater concern to Bookstaver were the lab's inadequate ventilation and its limited instrumentation for teaching organic chemistry. "I used to joke that we were teaching organic the way they did in the nineteenth century. About the most sophisticated piece of equipment we had was a melting-point apparatus," Bookstaver commented.

Influencing Renovation Plans and College Practices

Phase IV building plans that the college started in 2002 included moving a physics lab and using that space as an organic chemistry lab. Unfortunately, the money ran out before the college could undertake the lab renovation project. In the meantime, Dean Michael Banks, who went on to become vice president of Academic Affairs, kept the lab on his list of priorities. When the college received additional funds from the state's Lewis and Clark Initiative in 2007, he earmarked them for the organic chemistry lab. Banks started the planning process by pulling out a file that contained the yellowing copies of pages from the 1997 edition of the ACS Guidelines that Bookstaver had provided for the original Phase IV needs analysis.

"It was almost spooky how having those things in print from the ACS really spoke with some authority," Bookstaver said. He continued, "To an administrator who was a theater major, and who therefore knew nothing about chemistry, I think it was very helpful to have specific guidelines to use as a jumping off point, to say, 'OK if we are going to do a good job of chemical education, then these are the tools we need to give our people. Yes, it's going to be expensive, but it's just because that equipment is expensive—it's just what chemists use every day.'"

The influence of the Guidelines was most obvious when the planners worked with the architect to configure the students' workspace. After they tried several arrangements, it became clear that it would be nearly impossible to provide 4.5 linear feet of working bench space per student (as the 1997 Guidelines recommended) for the 24 students that the college had scheduled for each lab class.[1] When Bookstaver suggested the college lower the cap for the organic chemistry lab to 20 students, he was happily surprised that Banks readily agreed. No one on the planning committee objected on financial grounds, nor did they argue that less space per student would be good enough. "They really respected

that they [the authors of the Guidelines] are the professionals in their field," Bookstaver explained.

Initiating Curricular Changes

The new lab and the $285,000 worth of equipment[2] the college purchased for it (based on the equipment listed in the Guidelines [3]) have transformed the college's chemistry program. "I teach organic chemistry completely differently than I did five years ago," Bookstaver stated, going on to list some of the differences.

The new equipment allows students in organic chemistry to do fractional distillations and follow and analyze the fractions with GC. "This allows students to see why they get better separation with fractional distillation than with simple distillation," Bookstaver explained. Students also follow the progress of reactions with GC and GCMS. In addition, they work on a 60MHz NMR and learn how to use various spectrometers. "They leave here with a much more sophisticated set of skills than they [had] before," he said of the students, who typically transfer to baccalaureate biology and chemistry programs.

The curriculum changes also extend into the first-year chemistry courses. Bookstaver and another colleague have rewritten most of the General Chemistry I laboratory exercises to improve students' technical skills. They hope that as more students master basic lab techniques earlier in their academic careers, it will be possible to introduce more advanced instruments during General Chemistry II. The instructors eventually plan to have students collaborate with nearby universities on research projects.

The content of this case study was provided by John Bookstaver. Bookstaver joined St. Charles Community College's faculty as an adjunct instructor in 1994. He has been a full-time faculty member since 1998. Bookstaver holds a bachelor's degree in chemistry from the University of Missouri–St. Louis and one in philosophy from Cardinal Glennon College. He earned a master's degree in chemistry and a Ph.D. in organic chemistry from Washington University. In 2011, Bookstaver received the Governor's Award for Excellence in Teaching and an Emerson Excellence in Teaching Award.

Notes

1. *In Section 4.1, the current Guidelines recommend: "At least 50 square feet of net space per student should be provided, including lab tables and benches."*
2. *The college purchased, an HPLC and IR, AA, NMR, and UV/Vis spectrometers.*
3. *Instrumentation recommendations appear in Section 4.2 of the current Guidelines.*

Salt Lake Community College

Salt Lake City, UT

- IPEDS enrollment, Fall 2010: 34,654
- Type of community: Suburban
- Number of campuses: 14; chemistry is taught online and at 6 campuses; lab sections are available at 3 campuses
- Number of chemistry students, Fall 2011: 2,400
- Number of full-time chemistry faculty: 5
- Number of adjunct chemistry instructors: 20 (varies depending on semester)
- Structure: Chemistry Program is within the Natural Sciences Division
- Focus of chemistry program: Transfer
- Sections of the Guidelines used: 3.1, 3.2, 4.2, 4.3

Peter Iles, chairman of the Natural Sciences Division and a chemist, and **Luther D. Giddings**, assistant professor and coordinator of the Chemistry Department, used the *American Chemical Society (ACS) Guidelines for Chemistry in Two-Year College Programs* to

- Add full-time chemistry faculty members
- Acquire instrumentation
- Increase the computational software available to students

Demand for chemistry courses at Salt Lake Community College (SLCC) grew steadily after 2000 as unemployment increased and general economic conditions drove college-wide enrollment growth. The economic downturn also affected state finances and created budget constraints for the college. SLCC tried to save money by not filling some positions when full-time faculty members retired or left for other employment. Attrition left the Chemistry Department with three rather than four full-time faculty members in 2009. Every full-time faculty member was teaching an "overload," which was compensated at the rate paid adjunct instructors.

Full-time faculty members also guide students in service learning and research projects, for which they do not receive additional pay. "It has been our good fortune that when necessity has made it essential, people have been willing to shoulder an extra load even when that extra load is not compensated," Giddings said. Budget limitations added to the challenge of obtaining funds for new chemistry equipment and instrumentation.

Making the Case to Add Faculty

For several years in a row, Giddings requested additional full-time faculty when he and Iles met to identify the Chemistry Department's budgetary priorities. It was not until the release of the current version of the Guidelines in 2009 that the two men decided to cite the Guidelines to justify their formal budget request to Dean Clifton G. Sanders. They focused their advocacy on the recommendation for permanent faculty to teach more than 75% of the total chemistry offerings and the related recommendation that faculty and staff members not exceed 15 contact hours of classroom and laboratory instruction per week.

Sanders, who is also a chemist, values the Guidelines and understands their value but must weigh the needs of the chemistry program against those of the other science programs. In fact, Iles noted that the Chemistry Department has consistently had one of the highest student-to-faculty ratios (118:1) at the college. For this it is considered one of the most efficient departments at SLCC. However, even when every course section is filled to capacity, students are still being turned away from chemistry classes. While the college's enrollment system does not make it possible to track the number of students shut out of classes, Giddings said the number of students who have approached him to see if he can add them to closed sections increased in 2011 when the college implemented caps on the number of students and the number of course sections. The college's enrollment grew 26% from 25,129 in 2006 to 33,983 in 2010 while state support decreased.

Giddings said he decided to use the Guidelines for leverage in the budgeting process because other academic departments cited accreditation requirements and professional organizations' standards to obtain budget increases. Sanders confirmed that the Guidelines have provided leverage for funding decisions in recent years and that no one involved in the budgeting decisions questioned the validity of the ACS recommendations.

Sanders also found that the Guidelines were useful when he cochaired Utah's statewide curriculum committee. He went on to say that this group provided the framework for addressing 90% of the curriculum issues. The fact that all the public four-year institutions in Utah had ACS-approved programs also facilitated alignment between the two-year and four-year programs.

By 2010–2011, the SLCC Chemistry Department had five full-time faculty members. Because the department still has fewer full-time faculty than the Guidelines recommend, Iles said he plans to request funding for two or three additional full-time faculty members in the future.

Citing Guidelines for Equipment Expenditures

Giddings and Iles report having more success obtaining new instrumentation since they began citing the relevant recommendation in the Guidelines in their requests for equipment funds. The recommendation is that programs "have a suite of modern chemical instrumentation and specialized laboratory apparatus appropriate for the courses offered."

The Chemistry Department was allocated $80,000 two years in a row to upgrade laboratory equipment. In 2009–2010, the money was used to purchase a high-performance liquid chromatograph (HPLC), a BASi Voltammetric Analyzer, and a gas chromatograph–mass spectrometer (GC-MS) for use in organic chemistry courses. In 2010–2011, the department's request to purchase data processing software and 60 sets of sensors for students to use in General Chemistry was approved.

The recommendations in the Guidelines "are one of the tools I use. I'll use any tool I can. That's why if companies want to donate equipment they're replacing, we'll take that," Iles said. Donations from local companies have provided the college with a scanning electron microscope, an atomic absorption spectrometer, and three gas chromatographs. The microscope, a nanotechnology instrument, was donated to the Engineering Department, but chemistry students are gaining experience using it and other microscopes in the nanotechnology courses they are encouraged to take. For several years, the Biotechnology Department has allowed chemistry students to use its HPLC and GC-MS for their research projects.

"The ACS Guidelines and membership are very useful, but they are not the only resource," Iles concluded.

The content of this case study was provided by Peter Iles and Luther D. Giddings. In addition to serving as chairman of the SLCC Natural Sciences Division since 2003, Iles teaches two online chemistry courses as an adjunct faculty member. Before immigrating to the United States, Iles was a senior lecturer at RMIT University in Melbourne, Australia, where he led a research group in chemical sensors for 10 years. Iles earned a B.App.Sc. in chemistry from Victoria Institute of Technology (Australia), an M.App.Sc. in chemistry from the Footscray Institute of Technology, and a Ph.D. in chemistry from La Trobe University, Australia. Iles has 2 patents and more than 100 journal articles and conference presentations to his credit. He coauthored an electrochemistry textbook and a chapter in a textbook on photopolymerization for chemical sensors.

Luther Giddings, coordinator of the SLCC Chemistry Department, earned a Ph.D. in chemistry from Ohio State University and a B.S. from the University of Utah, where he majored in chemistry. He joined the SLCC faculty in 2001 as an adjunct instructor; he became a full-time instructor there in 2004. He was a guest lecturer at Ohio University and coordinator at Brigham Young University before joining SLCC's faculty. In 2004, Giddings received the Teaching Excellence Award from the SLCC Foundation and the Shining Star Award from the college's TRIO Program.

SF SANTA FE COLLEGE

Santa Fe College

Gainesville, FL

- IPEDS enrollment, Fall 2010: 15,745
- Type of community: Suburban
- Number of campuses: 7; only 2 have chemistry labs. A non-lab chemistry course is taught at a third campus.
- Number of chemistry students, Fall 2011: 924
- Number of full-time chemistry faculty: 3 (in the process of hiring 2 more in Fall 2011)
- Number of adjunct chemistry instructors: 4–7
- Structure: Chemistry is part of the Natural Sciences Department in the Division of Liberal Arts and Sciences
- Focus of chemistry program: Transfer
- Sections of the Guidelines used: 5.1, 5.3, 5.5, 5.10

Sture K. Edvardsson, the Natural Sciences Department chair at Santa Fe College and a chemistry professor, said the release of the *American Chemical Society (ACS) Guidelines for Chemistry in Two-Year College Programs* coincided with his and the full-time faculty's decision to re-examine the chemistry prerequisite course. The Santa Fe Chemistry Department used the Guidelines to

- Evaluate the alignment among Introduction to Chemistry, General Chemistry I and II, and Organic Chemistry I and II
- Guide the redesign of Introduction to Chemistry
- Encourage the use of process-oriented, guided-inquiry learning to teach Introduction to Chemistry

In 2009, the full-time chemistry faculty members at Santa Fe College recognized that the performance of students in Introduction to Chemistry needed to improve. Only 42% of the students who started the course completed it with a C or better. Even more troubling was the fact that many of the students who passed Introduction to Chemistry struggled to complete General Chemistry. While peer institutions in the region reported their students had similarly low success rates, the Santa Fe faculty felt they could do better.

Setting Improvement Goals

The curriculum development committee, comprising Edvardsson and all the full-time chemistry faculty members, agreed that during 2010–2011 they would revise the Introduction to Chemistry course. The new version of the course was launched in Fall 2011. The committee members had many conversations about the details of the revisions, but they agreed at the outset to use the ACS Guidelines to set goals for what they intended the course to accomplish.

"One of the principal organizing factors was the ACS Guidelines that we used as a starting point," Edvardsson said. The Guidelines were not the only resource the committee used, but he said they provided essential guidance about what the expectations should be for the course content, laboratory experiences, and student outcomes.

"The Guidelines came out at just about the right time in order for us to grab ahold of them and say, 'OK Let's start with this,'" Edvardsson continued. The college had used a previous version of the ACS Guidelines when it planned the renovation of its chemistry facilities in the late 1990s.

Revising the General Chemistry Curriculum

The curriculum committee worked backward from the existing Organic Chemistry and General Chemistry sequences to re-engineer the introductory course. Faculty members considered the expectations that students face when they advance to Organic Chemistry or move into quantitative analysis. They asked, "What does General Chemistry have to teach in order for students to be successful in Organic Chemistry?" Once the committee established what needed to happen in the two General Chemistry courses, they identified the concepts,

knowledge, and activities that students need to learn in the introductory course.

As part of this process, faculty members took a careful look at where their students encountered the most difficulty. Edvardsson said there are many reasons students do not do well, but the committee agreed that three deficiencies in particular had to be addressed in Introduction to Chemistry for students to succeed in subsequent courses. They were: 1) students' lack of math reasoning, in particular, their inexperience with applying algebra to solve contextual problems; 2) students' inability to visualize three-dimensional molecular objects; and, 3) students' low reading skills, which made it difficult for them to comprehend college-level chemistry textbooks.

The committee chose a new textbook and reformulated the course outline for Introduction to Chemistry. It also made sure the comprehensive departmental final exam aligned with the expected course outcomes.

Vice President of Academic Affairs and Provost Edward T. Bonahue said he considers the revisions to Introduction to Chemistry "a good example of the kind of continuous assessment that regularly takes place in the college."

Implementing Pedagogical Changes

Edvardsson explained that using the Guidelines led the faculty to talk about pedagogical techniques as well as the knowledge base students need. "There's a good description in there about how to engage students," Edvardsson said, referring to the Guidelines' encouragement of open-ended laboratory investigations and accommodation of various learning styles.

The faculty agreed to move toward process-oriented, guided-inquiry learning rather than continuing to use traditional lectures. Two faculty members were sent to guided-inquiry seminars. Two other faculty members attended a cooperative learning strategy program. When these individuals returned from the professional development programs, they shared what they learned with their colleagues.

Edvardsson explained that although the college values and respects individual faculty members' abilities to design their own classes, the expected learning outcomes identified during the curricular revisions require students to engage in lessons and to use processing skills. He went on to say that the committee working on the revisions decided the student-to-student interactions and guided-inquiry exercises were "the best and most obvious strategies to accomplish those goals."

According to Edvardsson, after the course outline was completed, Professor Mapi Cuevas led the faculty in developing a shell within the learning management system. It serves as a "course-in-a-box" for incoming faculty to get them started. This shell includes guided inquiry activities for the classroom and specific assignments designed to engage students in scientific inquiry.

During the orientation program for new faculty, the course activities are shared. New faculty members are also told of the college's expectations that they will incorporate the inquiry activities into their teaching. However, Edvardsson noted, that approach may not fit everyone's teaching style.

In addition to encouraging faculty to use the guided inquiry pedagogy, the college acquired additional equipment, including new software for students to use during laboratory exercises. This new software emphasizes observation, documentation, and analysis.

Santa Fe College launched the revised Introduction to Chemistry course in Fall 2011. The faculty hopes that at least 60% of the students who take the new course will pass it. The faculty will next revise General Chemistry I and II.

The content of this case study was provided by Sture K. Edvardsson, chairman of the Natural Sciences Department at Santa Fe College since 1990. He joined the chemistry faculty there in 1987. Edvardsson earned a bachelor's degree in chemistry from the Central University of Iowa and studied chemistry in the doctoral program at the University of Florida. During his time as a working chemist, he coauthored five articles on the degradation of aldicarb in soils.

Scottsdale Community College

Scottsdale, AZ

- IPEDS Enrollment, Fall 2010: 11,257
- Type of community: Suburban, contiguous to a Native American reservation
- Number of campuses: 3
- Number of chemistry students, Fall 2011: 630
- Number of full-time chemistry faculty: 4
- Number of adjunct chemistry instructors: 11
- Structure: Chemistry is included in the Physical Sciences Department within the Division of Mathematics and Science
- Focus of chemistry program: Transfer
- Sections of the Guidelines used: 4.1, 4.2

Doug Sawyer, chair of the Math and Science Division of Scottsdale Community College (SCC) and a chemistry faculty member, used the *American Chemical Society (ACS) Guidelines for Chemistry in Two-Year College Programs* to

- Set the square footage, bench space, and fume hoods of three new chemistry labs
- Influence the design of the organic chemistry lab
- Allot space for instruments

The building on SCC's main campus that had been used for science classes since 1972 was too small and had outdated safety systems. Demand for chemistry classes was so high and space so limited that general chemistry courses typically had 32 students. When the college obtained funding for a new Natural Sciences Building, faculty hoped it would a be a state-of-the-art building powered by geothermal energy.

Planning the New Natural Sciences Building

In 2006, Carl Couch, the vice president of administrative services, invited Sawyer to serve as the chemistry faculty representative on the Natural Science Building planning committee. Sawyer's task was to write the specifications for the new chemistry labs and interact nearly weekly with architects in advance of the start of construction.

Sawyer said he particularly relied on the Guidelines for the design of the organic chemistry lab. The infrastructure for the 13 fume hoods in this lab made it the most expensive of 16 laboratories in the building. The 46,000 square foot building also includes an aquarium, herbarium, microbiology preparation room, and planetarium.

The design of the entire building included some negotiations because of costs. The chemistry faculty had wanted four labs but had to settle for three because of budget limitations. The main items on the science faculty's wish list for the entire building were to use foam construction, rather than cement block, and to rely exclusively on geothermal energy so the building would operate off the power grid. The upfront costs of this ambitious plan, however, exceeded the budget.

Integrating the ACS Guidelines

There was never any debate among planners and lab designer, however, about following the recommendations in the Guidelines to provide at least 50 square feet of net space per student in the chemistry labs, according to Sawyer. It was also readily agreed to limit enrollment in Organic Chemistry I and II to 20 students and in General Chemistry I and II to 24. The other big item the Pysical Science Department received was a 1,300 square foot instrument room, which was several times larger than the tiny closet in which the department had previously stored instruments.

"Construction is remarkably complicated," Sawyer said, explaining that neither he nor any of the faculty grasped—until they were in the midst of the project—the detailed regulations that must be followed to comply with the Americans with Disabilities Act, OSHA, and fire code regulations. "There are

five different kinds of water in the lab," Sawyer said, noting the many details that have to be attended to just to make sure the water line for the eye wash is set at 80 degrees.

Budget limitations did require the chemistry faculty to pare its equipment requests and drop its plan to have an instrumentation assistant. Throughout the entire planning and construction process though, discussions were always "very collegial," Sawyer concluded.

The content of this case study was provided by Doug Sawyer. Doug Sawyer has served as the chairman of the Math and Science Division of Scottsdale Community College since 2004. He has been on SCC's faculty since 1992. Sawyer earned a bachelor's degree from Coe College and a Ph.D. in chemistry from Iowa State University. Sawyer coauthored Laboratory Inquiry in Chemistry, *Third Edition. He won the SCC Faculty of the Year Award for 2008–2009, and in 2009 the Scottsdale Charros, a nonprofit organization, selected him as Professor of the Year. He was part of a team that in 1999 discovered the first chemical evidence of an ancient ocean on Mars by analyzing rocks from the 1.2 billion-year-old Nakhla Meteorite.*

State Fair Community College

Sedalia, MO

- IPEDS enrollment, Fall 2010: 4,823
- Type of community: Rural
- Number of campuses: 4
- Number of chemistry students, Fall 2011: 100
- Number of full-time chemistry faculty: 1
- Number of adjunct chemistry instructors: 4
- Structure: Chemistry is within the Physical Education, Health, and Science Division
- Focus of chemistry program: Transfer
- Sections of the Guidelines used: 4.1, 5.1, 5.10, 6, 7.2, 7.3

Jack Lee Hayes, the only full-time chemistry instructor at State Fair Community College, relied on the *American Chemical Society (ACS) Guidelines for Chemistry in Two-Year College Programs* to restructure the college's chemistry program. He used the Guidelines to

- Revise the curriculum
- Shift the focus of class sessions to students doing chemistry and analyzing laboratory experiment results
- Add academic journals and scientific databases to the college library's collection for his professional development and students' research assignments
- Develop students' skills in laboratory safety and the use of chemical literature
- Influence facility decisions and set enrollment limits

When Hayes joined the faculty at State Fair Community College in 2005, it was his first full-time teaching assignment. The college's chemistry classes met for 50-minute lectures 5 days a week and one 50-minute lab per week. The schedule inhibited students' engagement in chemistry, and the curriculum did not address the philosophy of science.

Hayes turned to the Guidelines to set goals for himself and to explain his actions and requests to administrators. "In my background, my training, my culture, I like to have specific targets. I may not always go to them in the most linear fashion, but I like to know where I'm headed," he said.

Making Curriculum More Hands-On

Hayes first used the Guidelines to set parameters for himself and program goals. Then, usually with the Guidelines in his hand, he made his case to supervisors and colleagues for changes in policies and practices. He has overlapped the recommendations in the Guidelines about pedagogy, resources, and students' skills to make "appropriate and substantial laboratory work" the cornerstone of the chemistry program. The curriculum now incorporates hands-on, investigative chemistry activities, student-centered research projects, and group learning. He chose a textbook that uses an atoms-first approach to build students' knowledge beginning with familiar materials, like water. More recently, Hayes worked with local school districts and regional universities to ensure that the college's chemistry program aligns with the programs of the other sectors.

As soon as he could, Hayes changed the class schedules so that sections meet fewer times in multi-hour blocks rather than every weekday for 50 minutes. "You need more than 50 minutes, because if you only meet for 50 minutes, you barely have time to say, 'OK, yesterday we were doing this, and now we're going to do this, and ... for tomorrow you need to do this,'" he explained. Hayes finds that students show improved comprehension and information retention when they do experiments and discuss them immediately afterward during the longer-format class.

Less frequent—but longer—class sessions also help State Fair's students, who typically have long

commutes to the main campus or a campus center from their homes in the 14-county Central Missouri district. The hybrid version of the Introduction to Chemistry course is a popular option for students who are not science majors. They come to campus once a week for extended, in-person discussions and hands-on labs to supplement the course's online content.

To avoid being the "sage on the stage," Hayes instituted a "studio" lab for all the chemistry courses. This format combines his instruction with class discussions and laboratory activities. He usually has students conduct demonstrations that he incorporates into his presentations. He also delegates activities for small groups of students to complete, analyze, and report on to the entire class.

Enforcing a Dress Code as Part of Safe Laboratory Operations

Because students must arrive at every class "prepared to handle chemistry," Hayes used the Guidelines to set safety standards and enforce a dress code. With a large portion of students' grades based on the lab experiments and discussions, there have been only a few times when Hayes has had to send students away for inappropriate attire.

The dress code that Hayes created for chemistry at State Fair Community College was influenced by his industry experience. It requires that students' shirts have fabric within four fingers of the clavicle notch. Sleeves must cover students' armpits during normal motion, and fabric must cover their midriffs at all times. Pants or skirts must go all the way down students' legs to shoes, which must cover heels and toes. Hair must be pulled back, too. Hayes keeps extra shirts for students to use as lab cover-ups but has sent away students wearing sandals or pants with holes. The administration has backed Hayes' enforcement of a dress code for chemistry.

Adding a Research Component to Courses

The college's administration has also supported Hayes' requests for additional chemistry journals and databases. He explains that, "We did not have a good science database in the library, and I approached them and said 'Both I, as an instructor, and my students need to have access to a reasonable number of journals.' Now amazingly, for the most part they said 'OK.' I think it helped because most of the time when I made requests I would reference ... best practices as stated by the *American Chemical Society Two-Year [College] Chemistry Guidelines.*"

Hayes encourages students in every course to learn how to use scientific journals, evaluate information, and conduct research. To gain permission to handle reagents, students must provide their own materials safety data sheets. These summarize information about a chemical's structure, uses, and hazards and also cite where the students found the information.

To build students' critical thinking skills, Hayes requires them to find and analyze the original papers describing the research studies reported in the news. For nonscience majors, the lab final is an extrapolation or extension of a previous experiment. For science and engineering majors, Hayes requires a semester-long group project with a presentation of results.

Setting Class Size

Hayes also used the recommendations in the Guidelines to provide 50 square feet of net space per student and to meet other facility recommendations when the college renovated the chemistry labs on the main campus and started offering chemistry at off-campus centers. Following the 50-square-foot guideline is not easy. At two off-campus centers, where chemistry courses were offered for the first time in 2011, the small size of the laboratories has meant enrollment must be limited to 12 students, rather than 24. In addition, and also based on the Guidelines, Hayes had a portable eye wash station added to one center room that did not have a water supply line.

Even in the new science building that opened on the main campus in 2009, adhering to the 50 square feet per student standard means chemistry class sizes are limited to 20 students. Hayes describes the planning of the new facility as a "good interactive process." He said administrators did not argue for placing more students in the new lab when he pointed out the limitation suggested by the ACS Guidelines.

"A large portion of the way chemistry runs at State Fair is formed by the Guidelines. I use them ... as my boundaries, my objectives, what I'm heading for, and then I don't have a contentious relationship with my supervisors," Hayes concluded.

The content of this case study was provided by Jack Lee Hayes. While serving in the U.S. Navy, Hayes worked as an engineering laboratory technician. He then worked for 10 years for a radioactive waste remediation company. Hayes decided midcareer that he wanted to teach chemistry, so he earned his bachelor's degree at Western Montana College. From there he went to Indiana University, where he earned a master's degree in chemistry. He also earned a master's degree in adult education and distance learning from the University of Phoenix. During graduate school, he "fell in love" with community colleges while teaching as an adjunct chemistry instructor at Ivy Tech Community College of Indiana. He has been at State Fair Community College since 2005.

West Shore Community College

Scottville, MI

- IPEDS enrollment, Fall 2010: 1,522 students
- Type of community: Rural distant
- Number of campuses: 1
- Number of chemistry students, Fall 2011: 110. The college started an Early College High School for Science, Technology, Engineering, and Math (STEM) in 2011–2012; 40 high school students are in the inaugural group.
- Number of full-time chemistry faculty: 1
- Number of adjunct chemistry instructors: 0
- Structure: Chemistry is part of Science Department that includes one physics instructor and two biology instructors.
- Focus of program: Transfer
- Section of the Guidelines used: 4.1–4.2

Sonja S. Siewert used the *American Chemical Society (ACS) Guidelines for Chemistry in Two-Year College Programs* to

- Inform plans for a new science wing
- Assign priorities in the design negotiations
- Ensure state-of-the-art laboratory design

West Shore Community College's $4.8 million addition to the Arts and Science Building replaced a 1970s-era building that had never been updated. The college administration recognized that the science facilities needed to be updated for safety reasons. There was general consensus on campus and in the community that the old chemistry lab in a decrepit building should be replaced. The lab had just one fume hood, no chemical storage space, and asbestos table tops.

Planning the New Wing

Siewert and her Science Department colleagues were asked for their input years before construction began in 2005. "We were heavily involved from the beginning. We were the planning committee because it was only the science wing being built," she said.

Before the first meeting with the architect, science faculty members visited four other colleges that had recently updated their science facilities. Following these site visits, faculty members created a list with features that they did and did not want. They also sketched out some plans themselves in an effort to be as prepared as possible. The ideas were refined in a series of meetings, which began in 2001, with the administration and the architect.

Making Necessary Concessions

In keeping with the recommendation in the Guidelines for a maximum of 25 students per laboratory section (20 for organic laboratories), Siewert and her colleagues made small laboratories a priority. However, they needed to make some concessions in the negotiations with administrators in order to maintain the small labs.

For instance, the faculty originally requested a lecture hall for 60 students, but the administration did not want one this large. In retrospect, Siewert said the faculty is happy they lost on that point. The consistently small class sizes result in more interactions between faculty and students and richer learning experiences.

Additionally, Siewert had wanted dedicated labs for each of the three types of chemistry courses she teaches: Introduction to Chemistry, General Chemistry sequence, and Organic Chemistry sequence. The budget and space available allowed for just one chemistry lab. She therefore does all the prep work for the laboratory sections and places the chemicals on three different carts—one for each course.

Using the Guidelines to Influence Lab Sizes

While working with the architect, Siewert referred frequently to the *ACS Guidelines for Chemistry in Two-Year College Programs*. She remembers particularly advocating for the chemistry lab to have space for 20 students. "We designed all of our labs for all the science programs with that recommendation, with 20 students max, which has been terrific," she said.

Michael McKinney, head of the Science and Math Division, agrees that the ACS Guidelines "helped sway the rest of the planning committee to limit the size of the science labs to 20 students."

In addition to being accessible for students with special needs, the 1,052-square-foot chemistry lab has a chemical storage room with a chemical refrigerator, a prep room, and a glassware room. "We have a very open lab so you can see everyone all of the time.... You know what they do and do not know. That's probably the biggest part—that hands-on [part]. I know if they are fooling around in the corner or just doing the bare minimum to get by and I call them on it," Siewert explained.

The content of this case study was provided by Sonja S. Siewert, who has been teaching at West Shore Community College since 1998. She previously taught four years at Northland Community and Technical College. Siewert earned her Ph.D. in physical chemistry at Montana State University. Her bachelor's degree is from St. Olaf College, where she majored in chemistry. Her dissertation research was published in three journals. Siewert has received Faculty Excellence Awards at both West Shore and Northland colleges. She has been using Process Oriented Guided Inquiry into Learning to teach organic chemistry for five years.

WESTERN PIEDMONT COMMUNITY COLLEGE

Western Piedmont Community College

Morganton, NC

- IPEDS enrollment, Fall 2010: 3,195 students
- Type of community: Rural
- Number of campuses: 1, with 2 specialized off-campus centers
- Number of chemistry students, Fall 2011: 165
- Number of full-time chemistry faculty: 3
- Number of adjunct chemistry instructors: 0
- Structure: Chemistry is part of the Science and Mathematics Department, which is within the Division of Science, Engineering, and Mathematics
- Focus of chemistry program: Transfer and technician education
- Sections of the Guidelines used: 3.2, 5.1, 5.8, 5.12

C. Nadine McGrady, head of the Science and Mathematics Department, used the *American Chemical Society (ACS) Guidelines for Chemistry in Two-Year College Programs* to

- Revise the curriculum for General Chemistry I and II
- Make laboratory exercises more investigative
- Advocate for a reduction in faculty contact hours

In 2006 and 2007, Western Piedmont Community College (WPCC) was trying to keep its Organic Chemistry I and II classes. So few students were completing General Chemistry I and II at the rural college that enrollment in the two-course organic chemistry sequence had dwindled to three or fewer students per semester. Whenever enrollment in any class drops below eight or so, the deans must scrutinize and justify running the class in order to ensure cost effectiveness. Organic Chemistry I and II were two of the classes that required justification and were in danger of cancellation.

Restructuring the Curriculum

"We just didn't have the clientele," McGrady said. Despite the low enrollments, she and the college's two other chemistry instructors thought it was important to continue offering the two-course organic chemistry sequence for students who are pursuing chemistry degrees. To prevent the cancellation of Organic Chemistry I and II, McGrady and her colleagues restructured several aspects of the department to build students' interest in chemistry and encourage their persistence. The *ACS Guidelines for Chemistry in Two-Year College Programs* recommends that two-year colleges offer the full organic chemistry sequence for transfer students (when appropriate); the *ACS Guidelines and Evaluation Procedures for Bachelor's Degree Programs* requires full sequence as needed.

McGrady asked John Kiser, the newest member of the department, to revise the curriculum of the general chemistry sequence (Chemistry 151 and 152). Because many of Western Piedmont's chemistry students transfer to Appalachian State University, which has an ACS-approved program, he used the ACS Guidelines to set the goals for what the revamped courses should cover.

Kiser enjoys a unique perspective on what WPCC's students need to succeed when they transfer. He attended the college himself and was so inspired by the quality of the instruction he received in science and math that he became a chemistry instructor. Having graduated from WPCC in 2002, Kiser transferred to Furman University, where he earned bachelor's and master's degrees in chemistry. In 2005 he returned to WPCC as an adjunct instructor. He also taught full-time at Isothermal Community College for two and a half years. In 2008 he was hired as a full-time instructor at WPCC. Kiser also currently teaches at Catawba Valley Community College as an adjunct instructor. Taken together, these credentials made him a good choice for tailoring WPCC's general chemistry sequence to the needs of the students as well as the requirements of the curriculum.

For many years, North Carolina's public community colleges and universities have had common course numbering and seamless articulation for the general education core. The core includes Chemistry 151 and 152. Although the state system provides a brief description of what each core course should cover, it allows colleges to structure curricula, choose texts, and design laboratory exercises.

To Kiser, an atoms-first approach in General Chemistry I (Chemistry 151) seemed more appropriate than the traditional chemistry curriculum. He also thought that integrating thermodynamics throughout General Chemistry II (Chemistry 152) would improve students' comprehension and engagement. Basing his approach on knowledge he gained at a professional development workshop, Kiser added the student learning outcomes to the syllabi of the courses.

To follow through on the recommendation in the Guidelines to use "appropriate and substantial laboratory work," Kiser and McGrady have developed more hands-on activities and investigative laboratory exercises for both courses. They used the College Board's Advanced Placement (AP) course information to identify lab activities that provide the breadth and depth to prepare students for transfer and higher-level science classes. They referred to the online version of the AP Guidelines and Advanced Chemistry with Vernier. Students use Vernier probes in Chemistry 151 and Chemistry 152.

In 2010, the college was recognized by the system office as "Exceptional" for its performance on a number of measures. One of these relates to students successfully completing the chemistry classes. It measures the performance of transfer students at their receiving institutions. WPCC received extra state money in part because 89% of its transfer students achieved a grade point average of 2.0 or greater after 2 semesters in a University of North Carolina institution. The Science and Math Department was awarded (and used) $35,000 in additional state funds in 2010 and 2011 to purchase software, sensors, and other instruments to use in the redesigned lab activities.

"I have a wonderful faculty ... they are very 'in tune' with accountability. We are not afraid of it, but we are also very in tune to communicating to the students exactly what is expected and to be more student-centered than teacher-centered," McGrady said. Accountability measures from the state and the Southern Association of Colleges and Schools provided another nudge to clarify the course content and expectations to students. "You can't hit a moving target. And so if we set the target up front and say 'here it is' and don't move it ... it is just clearer focus for everyone involved," McGrady said.

Kiser added, "In general I think the ACS Guidelines are really helpful. I think they are good at giving ideas of what you should shoot for when you are planning out your chemistry program, your course offerings, your teaching load, the administrative support that you need." He feels that it is beneficial both to refer to guidelines from a professional organization and to share them with the administration, as when structuring or restructuring a program. Having recourse to professional guidelines can be particularly helpful when questions about effective practices arise.

Adjusting Contact Hours

Revamping the chemistry program also involved reducing chemistry faculty members' contact hours, in accordance with the recommendation in the Guidelines that "each laboratory contact hour should be equivalent to a classroom contact hour" and that contact hours should "not exceed 15 total hours per week." To accomplish this, McGrady has reassigned faculty to make better use of each person's strengths.

Western Piedmont Community College's official policy requires faculty to teach 18 work units in the fall semester and another 18 in the spring. Each lecture hour equates to one work unit and each lab hour equates to two thirds of a work unit. Chemistry and other science instructors at WPCC typically had to teach three courses in one semester and four during the next semester to average 18 work units per semester. Teaching four chemistry courses with labs accounted for 24 contact hours.

Once McGrady became department head in 2008 and initiated the curriculum revisions, she began advocating for a reduction in work load for the chemistry faculty. She started by informing Michael Daniels, dean of the Division of Science, Engineering, and Mathematics of this difference between the current college policy and the recommendation of 15 contact hours in the Guidelines.

Daniels' response provides a useful map for navigating the competing needs of institutions, students, and faculty. He first pointed out that the college workload policy was in line with those of other, similar community colleges in the region. Then, he indicated to McGrady that he understood her concerns. For the last three years, he has allowed the chemistry faculty to reduce their time with students to an amount a bit closer to 18 contact hours versus 18 work units.

In explaining how he found the middle ground, Daniels noted that the college gives deans (with vice-presidential approval) some discretion in the matter of contact hours. It allows the deans to consider the number of class preparations, new courses, and special projects with which the faculty members are involved. "The college is in the process of evaluating our teaching load policy, and I will refer to the ACS recommendations in my attempt to help us reach a more equitable solution," Daniels wrote in an e-mail.

Analyzing the Results of the Changes

By offering the same courses as before, but in fewer sections, the chemistry instructors have been able to focus on quality.

McGrady, who describes herself as an educator first, then a chemist, has taken on all the Chemistry 151 classes. She uses a lot of analogies and translates technical terminology into more commonly used words to "hook" students on chemistry.

"I tell them there's a chemistry way of saying this and there's the McGrady way of saying this. And so I just try to make chemistry more approachable, student friendly. Comfortable." McGrady tells students, "It's not a scary thing. It's not magic. You, too, can learn it."

Kiser teaches Chemistry 152 using a service learning project, along with the regional Science Olympiad competition, to increase students' interest. Kiser's master's degree research and thesis focused on thermodynamics and equilibrium, the two topics covered extensively in Chemistry 152. Meanwhile, Stacey Johnson, whose master's thesis was on organometallic chemistry, teaches Organic Chemistry I and II (Chemistry 251 and 252).

The revisions appear to be working. Although the college's overall enrollment has declined slightly (due in part to a state-mandated program elimination), the number of students completing Chemistry 151 has climbed steadily from 40 students in 2005–2006 to 85 in 2010–2011. Eight students were enrolled in Organic Chemistry in Fall 2011, compared to 3 in Fall 2010.

The content of this case study was provided by C. Nadine McGrady. She has been a member of Western Piedmont Community College's faculty since 1995. Before that, McGrady taught high school chemistry for 17 years. She earned her bachelor's degree in physical sciences and master's degree in earth science—with additional hours in chemistry—from Emporia State University. (The university was previously known as Kansas State Teachers College.) In 1993, McGrady received the Distinguished Educator and Mentor Award from the North Carolina State University Physical and Mathematics Sciences Foundation. In 2005, McGrady received WPCC's Excellence in Teaching Award.

Yavapai COLLEGE

Yavapai College

Prescott, AZ

- IPEDS enrollment, Fall 2010: 8,410
- Type of community: Small city
- Number of campuses: 3 campuses and 3 centers. (General, organic, and fundamental-level chemistry are taught at the Prescott campus. General and fundamental chemistry are taught on the Clarkdale campus. Fundamental chemistry is offered at the Chino Valley center.)
- Number of chemistry students, Fall 2011: 200
- Number of full-time chemistry faculty: 3
- Number of adjunct chemistry instructors: 1
- Structure: Chemistry is part of the Science and Health Division
- Focus of chemistry program: Transfer and allied health technician education
- Sections of the Guidelines used: 3.2, 4.2

Paul E. Smolenyak, a chemistry professor at Yavapai College, has used the *American Chemical Society (ACS) Guidelines for Chemistry in Two-Year College Programs* to

- Review programs
- Justify equipment requests
- Advocate in favor of one-for-one recognition for instructional time during lab sections

Administrators at Yavapai College accept chemistry faculty members' use of the Guidelines when they review the chemistry program's content and purchase equipment. Efforts to implement the recommendations in the Guidelines regarding teaching hours are still ongoing.

Guiding the Chemistry Program

The Guidelines serve as an authoritative reference for the chemistry faculty during the college's periodic review of its programs. The internal institutional process requires each discipline to run enrollment numbers and check other data to make sure that there is sufficient student interest to justify expenses. Accreditation agencies expect periodic program reviews, and institutions that do not routinely review their programs can jeopardize their accreditation.

The most recent review, completed by the chemistry faculty in 2011, included a question that asked whether there is any advisory agency or other organization associated with the program. Smolenyak said his answer was, "Yes," and he noted that he and his colleagues try whenever possible to follow the American Chemical Society's recommendations as contained in the Guidelines.

Justifying Instrumentation Purchases

Smolenyak cited the recommendations in the Guidelines that "programs should have a suite of modern chemical instrumentation and specialized laboratory apparatus" in his formal requests for equipment purchases exceeding $1,000. The college has a chemistry supply budget for chemicals and other supplies routinely used in labs. In 2011–2012, $13,600 was allocated for chemical supplies.

Since 2004, the college has purchased an FTIR, a proton probe, a computer control unit for a donated NMR, and three gas chromatographs.

"I'm not sure how much the ACS Guidelines made a difference, but I was at least able to cite them when I wrote up my rationale for capital equipment outlays," Smolenyak said, adding that the college has historically been supportive of equipment that provides students with hands-on science experiences.

Ongoing Effort to Gain Full Compensation for Lab Time

Several times with different administrators during the 12 years he has worked at Yavapai College, and speaking as the most senior member of the chemistry faculty, Smolenyak has used the Guidelines to request equal teaching credit or load hours for laboratory and lecture sections. Currently, Yavapai College counts an hour of lab as 0.7 load hours; a three-hour lab section equals 2.1 load hours.

To fulfill their contractually required 15-unit teaching load per semester, chemistry faculty usually

end up spending more than 15 hours per week in classrooms and labs. In practical terms, Smolenyak said, calculating an hour in the lab with students as less than an hour of teaching means that science faculty spend more time in actual instruction than faculty in other departments, such as English and math. "From our perspective, it is not equal pay for equal time spent," he said. The counterargument he has heard from English and math faculty members is that the disparity is a "wash" because they invest more time in grading assignments. He, however, insists, "That's not necessarily the case." For example, chemistry laboratory sections can require extensive preparation in terms of checking equipment, preparing solutions, cleaning up afterward, and grading laboratory reports.

College administrators have acknowledged Smolenyak's point during face-to-face conversations without agreeing to the recommendation contained in the Guidelines. "On several occasions I've brought up the fact that one-to-one lab loading is mentioned in the ACS literature, and ... they just nod their heads and say, 'OK.' That's about as far as that argument ever goes," he said. Smolenyak is past president of the Yavapai College Faculty Association, but Arizona is a right-to-work state. Consequently, there is not a faculty union at the college.

In discussions with the administration about one-to-one lab loading, it has been noted both that calculating hours this way is not the nationwide standard (despite the ACS recommendation) and that it would be quite expensive to implement. Smolenyak explains that administrators have said, "'Well, you know we could fund one-to-one lab loading, but how are we going to pay for it?' And basically the argument dies at that level because nobody is ever willing to commit the extra dollars that would be involved, because ultimately you would have to hire additional staff people." Smolenyak is not giving up, but given the current economic situation he is not aggressively pressing the issue.

The content of this case study was provided by Paul E. Smolenyak. He earned an associate degree from Yavapai College, then transferred to Northern Arizona University, where he earned a bachelor's degree in biology and chemistry. He taught at the secondary school level before earning a Ph.D. in analytical chemistry from the University of Arizona. He has been a full-time chemistry professor at Yavapai College since 2000.

Appendix

Appendix: Table of Contents for the *ACS Guidelines for Chemistry in Two-Year College Programs (2009)*